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Issue 17 Summer 2019

The Association for Science Education
Promoting Excellence in Science Teaching and Learning

why& how?
PRIMARY SCIENCE TEACHING TRUST

Contents

Issue 17 Summer 2019

Editorial Contributions

Main Articles

Practitioner – researcher articles

Regular features

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The Association for Science Education
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why & how? PRIMARY SCIENCE TEACHING TRUST

Editorial

● Suzanne Gatt

As the world keeps on changing at a fast pace, it becomes more difficult to distinguish between fact and fiction, between real and fake knowledge. As the famous chess player Garry Kasparov tweeted in 2016, '*The point of modern propaganda isn't only to misinform or push an agenda. It is to exhaust your critical thinking, to annihilate truth'.*

It thus becomes important to help future generations to learn, from a very young age, not just knowledge but, more so, how to navigate through different forms of knowledge of different levels of credibility. From early in life, children need to learn to question all the information they come across, check the validity of sources quoted, and take the initiative to test and challenge whatever statement or scientific 'fact' is thrown at them. They also need to be able to communicate their decisions and opinions in such a way that they can hold their ground solidly against arguments based on little or questionable evidence.

The reality presented by the world today also has implications for the type of pedagogical approach that we as teachers need to adopt when doing science with young children. While many are those teachers who have moved away from reading scientific knowledge from a book to one involving hands-on experiments, where scientific phenomena are experienced first hand, this may not be enough to deal with the new challenges of misinformation. Demonstration experiments that illustrate already given and stated scientific knowledge do not allow children to engage critically with scientific phenomena. Whether science involves reading about a topic of interest to find specific information, or interacting directly with the world to understand how it works, it does not give learners the opportunity to develop the skills to question, test, analyse and review their experience of their surroundings in order to obtain a measure of its validity. Such pedagogy still provides limited space for children to talk about, share and engage in argumentation about different ways in which the same observed occurrence can be interpreted and understood.

So what should the learning of science today aim to achieve, and what type of pedagogies have impact on both learning science and for engaging effectively with reality? There has been a lot of pedagogical development as well as research carried out on inquiry-based learning in science. Inquiry science usually involves children formulating questions or hypotheses, which they then go on and test through practical investigations. Children are expected to work in groups, developing shared understandings through social construction of knowledge as they search for answers in response to their initial question. It is only then, at the end, that they communicate their conclusions to others, and possibly engage in reflection on the validity of their conclusions.

Thus, inquiry may not be enough to help children to develop the skills needed to deconstruct the messages around us about the world. It is not enough to test one main idea, to know how to present and defend a conclusion. Children need to start early to compare competing proposals and explanations, to use research and argumentation in favour of one interpretation against a number of others being proposed simultaneously. New pedagogical approaches have to involve exploring actual situations, testing the veracity of statements found on the Internet, on Facebook, for example. It is only through such approaches that they can learn to engage effectively with science, following which they will be able to independently decide whether science-related information circulated and claims about science made by politicians and other players in society are valid or not. Only then can they decide, for example, whether climate change is real, or a hoax as some climate change sceptics claim. Thus, children learn scientific knowledge and processes of science alongside the process of fact-checking and ensuring rigour of background sources. Of course, this places even greater demands on early years and primary teachers, who already are themselves grappling with this new reality and, as they learn how to navigate through misinformation, they also help young children to learn how to deal with and counteract it.

All the articles in this issue consider different aspects of the real world and how it can be brought into young children's classrooms to make science relevant, as well as highlight its role in society. The paper by **Trew *et al*** takes the example of Santorio's work on the pulsilogium in the 16th century. Through using the mechanism to measure pulse rate, children learn science as they try to unravel how the scientist eventually worked out how the model could work.

In their paper, **Pedreira & Márquez** consider how young children interact with scientific phenomena in an area of exploration in a science museum, which was designed specifically for early years children. **Hansson & Leden** write about trade books (better known as reading books), and how educators can engage children in discussions on the accuracy of the science content, and whether scientists' work is reflected against objective facts. **Shallcross *et al*** describe examples of real cutting-edge science and how young children can investigate scientific phenomena starting from real scientific research.

PSTT also provide a fascinating look at the many benefits to be gained from schools holding designated **Science Days and/or Science Weeks.**

You are invited to read through the papers and be inspired by the initiatives described, so that children get to experience real science within a real context.

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A series of investigations using Santorio's17th century pulsilogium...

● Alison Trew ● David Taylor ● Joanne Welsman

...to help primary-age children develop scientific skills and understand the process of scientific research.

Abstract

Primary school children introduced to a long-forgotten and only recently rediscovered invention, Santorio's pulsilogium, have been able to develop their own scientific inquiry skills and deepen their understanding of the repetitive and problematic nature of scientific research and development.

We present the thoughts and ideas of children as they consider why and how a famous scientist from late 16th and early 17th century Italy developed an instrument to measure pulse. At the time of Santorio, even the best clocks did not have sufficient stability to enable pulse to be measured or expressed in beats per minute. The children were able to explain and debate in a highly effective way when they had explored the methodology of the pulsilogium, and had less difficulty than many adults in understanding the concept that the measurements obtained were comparative rather than absolute values.

Keywords: Pulse, pendulum, Santorio, measure, scientific inquiry

Introduction

In November 2015, a collaborative project involving university researchers, teachers, schoolchildren and members of the public began at the University of Exeter, UK. The aim of this project was to recreate the 17th century medical laboratory of Santorio. Santorio was a physician and professor of medicine at Padua University in the late 16th and early 17th century.

Amongst his many inventions were a number of instruments for measuring pulse, which he named *pulsilogia* (Bigotti *et al*, 2017).

In the 21st century, most of us are surrounded by instruments taking measurements: computers, tablets and mobile phones, all measuring numerous variables such as time, temperature, pulse, sugar levels, number of steps walked, to name but a few. Because it is possible to collect so much data in the modern age, we are presented with ever more statistics designed to influence and change how we live our lives. Children are growing up in media-rich homes and digital technologies are an important part of their lives (Chaudron, 2015). Recent evidence suggests that primary age children trust machines to such an extent that they will modify their behaviour to conform with robots (Vollmer *et al*, 2018). However, a digital read-out from any device is only the result of a measurement process. Sources of error are present at each stage in that process and all add to the measurement uncertainty, so a measurement has little meaning unless these sources of error are quantified and assessed. It is important that educators teach children to question data. Through a series of investigations using models of Santorio's pulsilogium, children have worked scientifically to consider how and why measurements are taken and evaluated old methods with modern technology.

Aims

We wanted to provide a project for primary school children to enable them to experience the challenges faced by real scientists, both past and present. After using a reconstruction of Santorio's pulsilogium to measure pulse with primary-age children, we thought that learning about the development of this instrument provided a suitable real-life context that children could understand.

Our aims in this project were:

- To develop children's scientific inquiry skills (planning, observing, measuring, evaluating) and scientific literacy;

- To help children consider the meaning of measurements, scales and appropriate units of measurement;
- To provide an opportunity for children to experience the nature of scientific research by solving problems, collecting data and repeating measurements, and to understand the difficulties faced by scientists in the past and today; and
- To reflect on the value of old technology and compare with new technologies by encouraging children to think about validity of the measurements and numbers produced by digital equipment.

Development of Santorio's pulsilogium

Born in 1561, Santorio studied mathematics in Venice before graduating from Padua University, where he was a contemporary of Galileo. Although for the most part forgotten, to those who study the history of medicine in the early modern period, Santorio is best known today for his discovery and study of what he called 'insensible perspiration' – what we now call metabolism. However, this was only one of his many innovative contributions to medical science. Santorio was the first person in the history of medicine to recognise the importance of precise measurement in the diagnosis of disease; to aid his work he invented 20 instruments, many of which are still in use today but in much more modern forms.

In Santorio's time, the laws of motion were only just beginning to be understood; although it was known that a pendulum could reproduce precisely timed swings provided its arc of movement was small, no one at the time understood why. Santorio was the first person to make practical use of this property when he applied it to measurement of the pulse. Like many others of his time, he knew that the period of a pendulum – the time it takes to move from its at-rest position out to one extent of its swing, back through the starting position, out to the opposite extent of its swing and then back to the centre – depends upon the length of suspension cord and is independent of the suspended mass (Nelkon & Parker, 1975). Hence, he reasoned that, by adjusting the length of the suspension cord, the motion of a pendulum could be made to synchronise with strokes of the pulse.

Santorio's beam-type pulsilogium enabled the operator to adjust the period of the pendulum whist it was in motion and read off an indirect indication of the suspension cord length from a scale marked on the beam (Bigotti *et al*, 2017).

The concept of pulse as a rate, i.e. beats per minute, was unknown to medicine at the time of Santorio, because it was not possible to measure short time intervals accurately and reliably. Most clocks at that time were not equipped with minute hands because their rate was erratic in the short term; even the best of them couldn't measure 24 hours consistently to better than ± 15 minutes (Jespersen & Fitz-Randolph, 1999).

Assessment of the quickness or slowness of the pulse at the time of Santorio was at best only an estimate, depending on the skill and experience of individual physicians. Santorio improved on this by using his pulsilogium, which is the first instrument of precision in medicine (Bigotti *et al*, 2017; Bigotti & Taylor, 2017), and expressing pulse as degrees on a numerical scale; Santorio's 'Degree of the pulse' was expressed as a single number read from a scale on the instrument. Santorio's pulsilogium is sensitive to very small changes in the pulse, which are beyond the ability of any physician to perceive unaided.

A woodcut engraving of Santorio's beam-type pulsilogium (Figure 1) shows the proportions of this instrument:

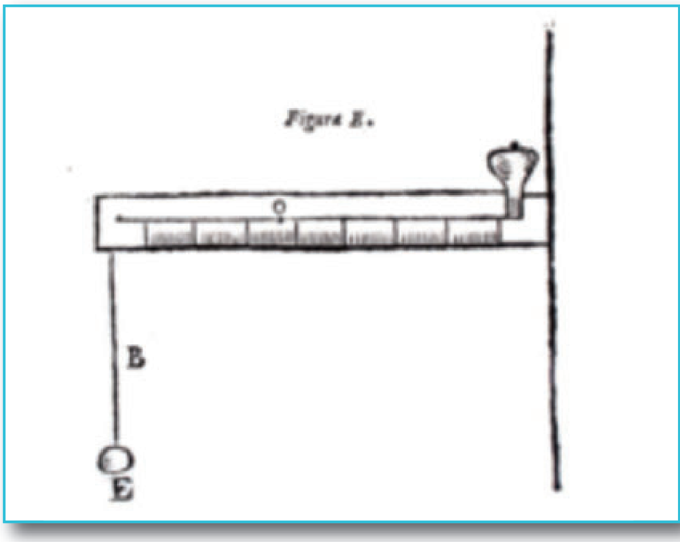


Figure 1: Original woodcut engraving of Santorio's beam-type pulsilogium. (This image is from Santorio's *Commentary to Avicenna's Canon*, published in Venice in 1625.)

Examination of the image in Figure 1 and historical records led to the sketch of the instrument shown in Figure 2, and the creation of a historically accurate reproduction (Bigotti & Taylor, 2017):

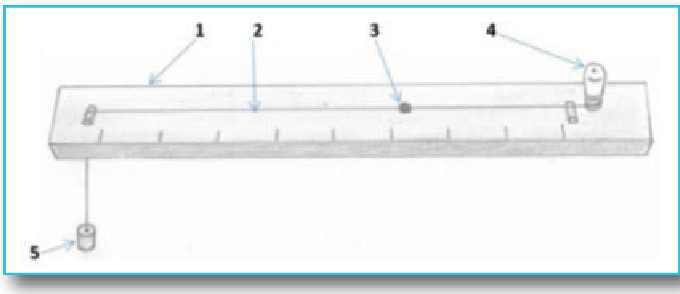


Figure 2: A sketch of a replica of Santorio's pulsilogium, where 1 is the support beam and scale; 2 is the linen thread; 3 is a bead; 4 is a tapered peg; and 5 is a pendulum bob.

Santorio's methodology for measuring pulse

Rotation of a tapered peg adjusts the length of pendulum suspension cord, which is indicated by the position of the wooden bead along the scale (Figure 2). Use of a taper enables the peg to be locked in place once set. Whilst feeling the patient's pulse, the tapered peg is rotated until the limits of the pendulum swing coincide with beats of the pulse so that there are two pulse beats per pendulum cycle. At this point, the number on the scale adjacent to the wooden bead gives an indirect indication of the speed of the pulse; this reading is recorded for future reference. Note that, as the pulsilogium is sensitive to very small changes in the pulse, it is essential that all readings are made relative to the same edge of the bead. It is easier and more reliable to read from an edge rather than estimate the position of the bead centre.

In order to compare the patient's pulse with an earlier reading, Santorio would have first set the wooden bead to the position previously noted and then compared the current pulse with the motion of the pendulum. By starting with the bead in the original position, it would be immediately obvious if the pulse had changed. After adjusting the instrument to match the current pulse, the difference between the earlier reading and the current one shows the direction and amount of change in the speed of the pulse over the intervening period; this would have been essential to Santorio when assessing his patient's condition.

A photograph of the first historically accurate reproduction of Santorio's Pulsilogium is shown in Figure 3:

Figure 3: An historically-accurate reconstruction of Santorio's beam-type pulsilogium (Bigotti *et al*, 2017).

Children's investigations

We have presented a series of investigations that enable children to think about a problem as Santorio would have done when he was developing his pulsilogium. Very few resources are required. The children work in small groups using a wooden batten, some thread, some modelling clay and a strip of paper to construct their own model pulsilogium, which they can use to measure pulse. The investigations have been carried out with children aged 7-11 years in science clubs and in STEM workshops on science days, and with adults and children at a science festival.

Initial discussion

Rather than showing and explaining how the pulsilogium works, we introduced a reproduction of Santorio's pulsilogium to the children without any explanation and asked them to consider what it might be, how it worked and to explain why they thought this (see Ritchie *et al*, 2019 for a similar approach to instruments of this kind). Teachers could show the initial few seconds of the video clip at https://youtu.be/ddfUnd5E6EU, or a picture of it (Figure 3). Alternatively, children could be shown a simple model pulsilogium (see Appendix 1 for details on how to make one).

Some initial questions that we asked children were as follows:

- *What do you think this might be?*
- *Have you seen one before? Where? When?*
- *Which parts move?*
- *What does the scale tell you?*
- *What are the units of measurement?*
- *How would you use it?*
- *What would it measure?*

At this stage, the children do not know that the string can be lengthened and shortened. We found that responses from the children varied depending on their age and their prior experiences (as found by Ritchie *et al*, 2019) but, with support, most children made good suggestions and linked their ideas to evidence from their own experiences.

Here are some typical responses from children:

- *'I think it is a spirit level because it is long and horizontal'* (age 10).
- *'I think it is a weight measurer because you can put different weights on the end of the string'* (age 9).
- *'I think it is a stethoscope because you can put this part [indicates the bob on the end of the cord] on to your heart and it will measure through the string'* (age 9).

Here is an opportunity for children (with support from the teacher) to articulate scientific concepts, explore their ideas and address any misconceptions held in science. Though one child did suggest that the instrument could measure pulse through the string, they did not predict that the string was a part of a pendulum. None of the children we worked with proposed that the instrument measured pulse by synchronising the motion of a pendulum, and they were fascinated when we explained that this instrument was first made in about 1602 by an Italian scientist called Santorio, who used it for measuring the pulse of his patients.

Finding a pulse

Many children will have had their pulse measured in hospital or by their GP, so this is a good starting point for talking about pulse. Ask if any of the children can explain what was measured and how it was done. We found that many children aged over 7 years knew that their pulse is the heartbeat felt at different parts of their body, because they were old enough to have experienced visits to the doctor or hospital. We found that some children who have experienced a stay in hospital remember having a pulse meter put on their finger. Others remembered a tourniquet being put on their arm and others have had a stethoscope placed on their chest or back. You may find that you have a lively debate about where and how a pulse can be felt. Whilst it is good to mention several areas where the pulse can be felt, encourage the children to feel the pulse in their wrists, as this is the focus of the experiments here.

Units of measure – speculation and reasoning

We asked the children whether they knew in what units their pulse was measured. We found that some children describe pulse as 'number of beats' but do not know that it is measured as 'beats per minute'. A few of the older children were able to explain that beats are counted for a fixed time period so that the result is expressed as beats per minute. Note that it is not necessary at this stage to demonstrate measuring a child's pulse in beats per minute, as this may confuse the pulsilogium investigation. The children just need to be able to feel their pulse or a partner's pulse using two fingers (index and middle) on the wrist.

Having established that pulse beats could be counted for a fixed time period, we explained that, in 1600, there were no reliable clocks for Santorio to use. Ask the children if they can guess what Santorio did with his pulsilogium? Interestingly, we found that many children suggested putting the weight of the pendulum on the wrist, imagining that electricity (or perhaps infrared light) travelled along the cord to the numbers on the scale to provide a numerical reading. It is a reasonable suggestion when, in a child's life, so many things are made to happen as a result of electricity travelling through wires. Perhaps no more incredible than pointing a gadget at a machine to operate it when it isn't even attached; very few children have not used a remote control to operate a TV before they come to school. Encourage the children's ideas and talk about why some of the children's thoughts may or may not work, either now or in Santorio's day (Osborne, 2010; Mercer *et al*, 2009). It is worth saying at this stage that children should be given time to justify their ideas, even if they are not plausible and, similarly, children need time to consider and evaluate alternative ideas suggested by their peers (Mercer *et al*, 2009). A skilled practitioner will provide opportunities to consider not only why a 'right' idea is 'right', but also why a 'wrong' idea is 'wrong'. Using sentence starters can help children to develop skills of argumentation, e.g. *'I think … because …'*, or *'I don't agree because …'* (Mercer *et al*, 2009) and exemplified, for example, by Eley (2016). Just like scientists throughout history, children need to know that it is okay to say *'I've changed my mind. Now I think …'*. By following this approach, children will have a better understanding of the nature of scientific inquiry and the way in which scientists work when discussing their research.

Measuring pulse with a model pulsilogium

Show the children how to start the pendulum by holding the weight about 30 degrees (not more than 45 degrees) from the vertical and letting go (no need to push), and how to count the swing of the pendulum. This is easiest to do by counting at the limits of the pendulum swing, i.e. two pulse beats per pendulum cycle. Ask a child to count aloud in time with the pendulum. The next bit is trickier and needs to be done by a child who is confident in finding a pulse in someone's arm. This child should count aloud the beats of the pulse that they feel. Ask the group whether these two beats are 'synchronised' (occurring together). Explain that Santorio was able to obtain a value for the patient's pulse when it was synchronised with the pendulum. Ask for the children's suggestions as to how to adjust the swing of the pendulum so that the limits of its swing coincide with the pulse beats. Discuss their ideas, encouraging children to explain why they agree or disagree with others, as this allows the children to develop scientific literacy and demonstrates how to question the ideas of others in a positive and constructive way. The thread length should be shortened to quicken the swing of the pendulum and lengthened to slow it down.

Choosing a scale for the pulsilogium

Once the children can synchronise the swing of the pendulum on their pulsilogium with the 'patient's' pulse, the investigation moves on to ask the children what scale is needed on the pulsilogium:

- *How can you show that the pulses of people are different?*
- *How will you show that the thread is longer or shorter?*
- *Can you suggest a suitable scale to put on the beam?*
- *Will your scale use numbers or words or symbols to describe a person's pulse?*

It is interesting to hear the children's suggestions for scales. If they have seen one of the experimental reconstructions of Santorio's instrument, they may suggest centimetres because they saw that a metric tape measure was used to represent the scale. When we asked children for suggestions for scales along the beam, we found that they either chose some units associated with measuring length that they previously had heard of (cm or inches), or they wanted to invent a new scale with numbers.

Suggestions from children aged 9-11 years included:

- *'We could use a Lego brick to mark equal distances on the paper strip.'*
- *'Use your thumb to mark lines along the paper.'*
- *'Use a ruler [presumably a metric one] and put a mark every 5 cm.'*

When we have asked children in what units their pulse is measured, some were not able to provide an answer, but most explained that *'It cannot be cm'*. Responses from children included:

- *'It can't be centimetres because it's not "how long" is your blood.'*
- *'It isn't beats per minute because we didn't count for a whole minute.'*
- *'If we use Lego bricks, we can measure it in bricks.'*
- *'Measure it in thumbs using thumb prints.'*

Children appear not to have fixed ideas of units of measurement for the pulsilogium. Some children have asked, without prompting: *'Why do you need numbers when you could have pictures?'* Why indeed, when an emoji can explain just how 'well' a patient is or isn't (Figure 4)! A child who had musical instrument lessons decided to add musical terms to describe the speed of the pendulum and rate of the pulse: *adagio* and *largo.*

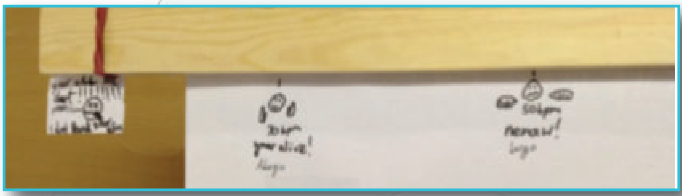


Figure 4: Children's emoji scales and musical terms on a model pulsilogium.

We discovered that adults, on the other hand, have preconceived ideas about measuring pulse and find it hard to remove 'beats per minute' from their minds. Some believe that the number marked on a cm scale on the beam is a value equivalent to beats per minute. At a public demonstration of Santorio's pulsilogium at a science festival, eight adults allowed us to synchronise the pendulum with their pulse. The scale on the pulsilogium beam was a metric tape measure. Indirect measures of pulse were taken from the scale and ranged from 29 to 48. More than one adult asked *'Is my pulse 30 beats per minute?'* Clearly, this cannot be the case: most adults have a resting heart rate between 60 and 100 beats per minute (NHS website, 2019). We also measured their pulse with a pulse meter and the range was 68 to 80 beats per minute.

Testing reliability

Once the children are confident using their pulsilogium and have recorded the pulse of a few people (using a numerical scale, a word scale or emojis), the next step is to determine how **reliable** the pulsilogium is to measure pulse**.** We know from controlled experiments that the pulsilogium is very accurate and reliable when tested by a trained operator against a stable source, i.e. a metronome (Bigotti & Taylor, 2017)**.** However, in practice, pulse measurements could be affected by:

- ***Biological error*** (internal error), meaning the natural variation in a person's resting pulse, as pulse rate is sensitive to many factors including emotions, illness, environmental conditions and previous exercise.
- ***Experimental error*** incurred by the persons taking the measurements (in the case of the pulsilogium, this could be two or three people), and two sources of variation need to be considered**:** firstly, **within observer variation** (how similar are the results of repeated measurements taken by the same person/group using a single pulsilogium?); secondly, **between observer variation** (how similar are pulse readings taken by different people on the same patient using the same pulsilogium?).
- ***Instrument error,*** meaning the variations in the behaviour of the equipment.
- ***Environmental influences,*** such as variations in temperature and humidity.

Ask the children:

- *What might affect the reading you observe from your pulsilogium?*
- *How will you know if your pulsilogium is reliable?*
- *How many times will you repeat your measurements?*
- *What could you do to try to reduce variability in your measurements?*

To address biological error, simple measures to reduce variation within the 'patient' could include asking them to lie very still with their eyes closed for five minutes before the measurements are taken.

Children should consider their sources of experimental error: whether the person counting the pulse ('pulse monitor') is accurate, whether the person counting the pendulum swings ('pendulum monitor') is accurate, whether the two 'monitors' are properly synchronised.

In the case of instrument error, consider what this could be for the pulsilogium:

- The pulsilogium might not be horizontal – this doesn't matter as long as the pendulum swing is not impeded.
- The swing of the pendulum might have been greater than 30 degrees from vertical.
- The pendulum swing started by a child might have been unsteady.
- A pendulum does not always swing in a straight line; sometimes the motion of the pendulum bob describes an ellipse or a figure of 8.

Encourage the children to repeat their pulse measurements, whilst keeping as many variables as possible the same. This may be challenging because the children may want to swap roles but, to properly investigate reliability, the patient, the pulse monitor and the swing monitor should be unchanged. It is worth reminding children that the nature of science research is repetitive and, as a result, is not always exciting during the data collection. It is, nevertheless, vital to the process of research and can lead to exciting findings.

We found that pulse readings in most cases were reliable using a pulsilogium with a hand-drawn number scale as shown in Figure 5. In this case, the same two children took the role of pulse monitor and pendulum monitor to reduce experimental error. They recorded indirect measurements of pulse for three different 'patients' and repeated their tests after about 30 minutes. In two patients, the second reading of pulse was very similar to the first. The change observed in the third child's readings was a source of speculation and the children suggested that the pulse increased because the 'patient' had been moving around so much (biological error) rather than a result of any observer variations (experimental error).

It is worth noting that the pulsilogia built in any one classroom will have different scales and so it will not be possible to compare these instruments directly with each other. Instead, they can all be compared with another instrument counting pulse, such as a metronome or an electronic metronome (Figure 6). The children used a metronome app on a mobile phone to produce 70 beats per minute and compared this with their pulsilogium reading. Every time they repeated this, the children were delighted that the indirect reading on their pulsilogium was very close (usually the marker on the thread moved less than 2 cm) to their original reading.

We noticed at this stage that the children were thinking about how to make their instruments more accurate and asking questions about improving the reliability of their instrument and their methodology:

- *'The marker is too wide, and we don't know which edge to look at – can we make the marker on the thread narrower?'*
- *'How can we make sure the patient is properly rested – shall we time them sitting still?'*

Comparisons with other methods of measuring pulse

Having repeated pulse measurements on the pulsilogium, the children should now have some understanding of whether their pulsilogium is reliable, but what about other more modern instruments that we use to measure pulse?

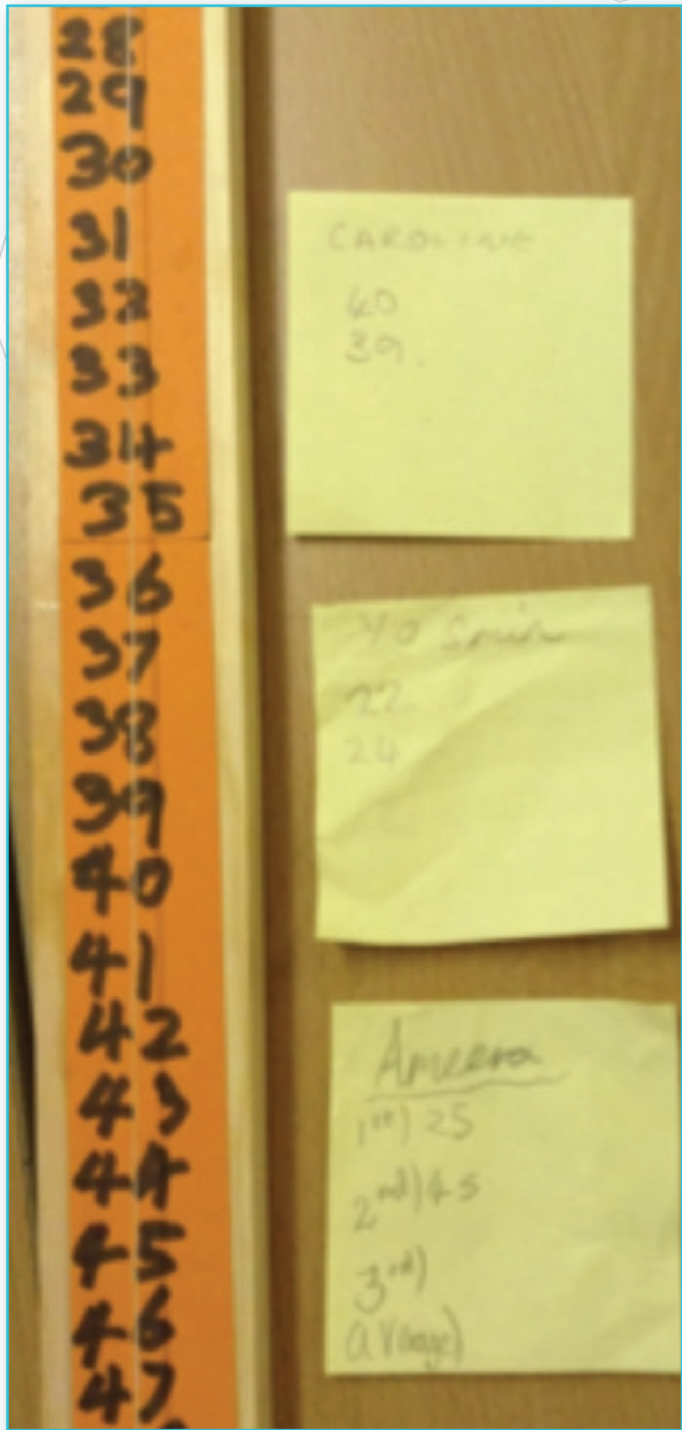


Figure 5: Repeated pulse measurements using a basic pulsilogium.

Figure 6: Children compare pulsilogium data with a metronome app.

Show the children how to measure their pulse by counting for a fixed period, for example, count pulse beats in the wrist for 15 seconds and multiply by 4 to ascertain the beats per minute. There is only one source of human error with this method. Children can compare reliability by taking repeat measurements by having two children recording the pulse of a third (one on each arm). What do the children think about the reliability of this method? How does it compare with the measurements they took on the pulsilogium?

Next the children could investigate the reliability of a modern pulse meter. These can be borrowed from a local GP surgery. Again, encourage the children to take repeat readings to determine the instrument's reliability and have children compare two pulse meters if possible, to find out how reliable the modern pulse meter is. If only one pulse meter is available, the children can simply compare their pulse that they counted in the first method with their pulse read from the pulse meter. They could be surprised by the results. Several wrist-worn heart rate monitors are available now. If you can borrow one of these, the children will be able to compare the reliability of these instruments too.

After looking at some different methods of measuring pulse, there are some important questions to consider with the children:

- *Which method do you think is the best for measuring someone's pulse?*
- *Can you say why this method is best?*
- *Are you surprised by any of your results?*
- *Are electronic / computerised instruments always the most reliable?*
- *What are the main sources of error in measuring pulse in each method?*

The last question is a big one to consider, but it is an important one for children because they are growing up in a digital world and are using technology in so many aspects of their lives. How reliable is technology? Modern instruments are also susceptible to error; differences have been shown between measurements taken by various makes and models of wrist-worn monitors (Kooiman *et al*, 2015; Shcherbina *et al*, 2017). It is very important to emphasise that 'digital' does not necessarily mean 'accurate'.

Other pendulum investigations

What happens to the pendulum period when the arc through which it swings is changed?

Ask the children to predict whether the pendulum period will be greater, less or unchanged if we change the angle from vertical that the pendulum is released from. The children could draw angles between 10 and 40 degrees from vertical on card and attach to the table behind the pendulum (Figure 7).

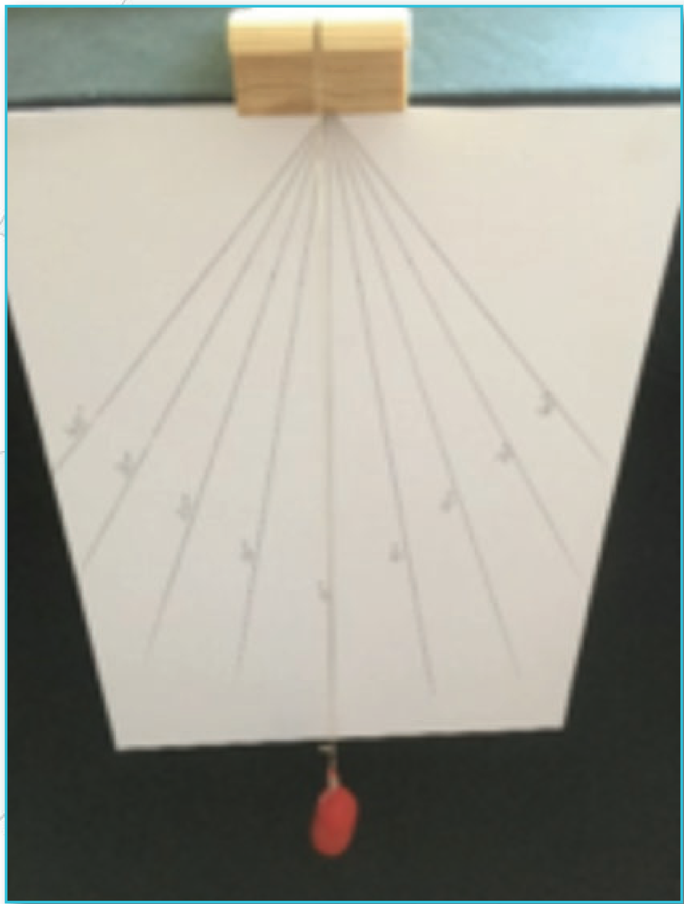
This would allow the children to release the pendulum from different angles and to record any variations: children could either count the number of complete oscillations in a fixed time period (we used 30 seconds) or use a timer to record the time taken for a fixed number of periods.

It would be interesting for children to compare these methods and this allows children to appreciate that questions can be investigated and answered in different ways. The children should find that the period does not depend on the amplitude, provided the angle is kept small (less than 30 degrees).

What happens to the pendulum swing when the pendulum mass is changed?

Provide weighing scales and ask the children to investigate what happens to the pendulum period when the mass of the pendulum 'bob' is increased.

Figure 7: Investigating the arc angle of the pendulum.



Again, children can either count oscillations in a fixed time period or record the time for an agreed number of oscillations. The children should find the mass of their modelling clay bob has no effect on the pendulum period.

Where else is a pendulum used?

Ask the children where they have seen a pendulum used. Some may have seen grandfather clocks. Children can research how the pendulum is used to move parts within the clock mechanism to record time.

How can the pendulum be used to divide time? (Egg timer investigation)

Provide the children with a 1-minute sand timer and ask them to create a pendulum that can record 1 minute. If the children have previously investigated the effect of the pendulum weight and angle of swing, they will know that only the length of pendulum needs to be changed to influence the period. Can they change the length of the thread so that the pendulum swings a fixed number of times in one minute? Can the children then tell you the time taken for one period? Can they predict how many periods they will need to count for 3 minutes? Children can test this out using a 3-minute timer to see if their predictions are correct.

Discussion

Our main aim in creating these investigations was to develop children's scientific inquiry skills (Mercer *et al*, 2009). Introducing Santorio's 17th century pulsilogium to primary-age children and exploring its history, development and reliability provides an opportunity for inquiry-based teaching and the development of children's science inquiry skills. This teaching approach, when learners try to make sense of new experiences or solve a problem, is well documented (Harlen, 2014; Harlen, 2018). Children undertaking inquiry in science will: plan how to investigate, work collaboratively with others, gather data, interpret data, express their ideas using appropriate scientific terms, and reflect about the processes and outcomes of their inquiries. In these pulsilogium investigations, children had to work collaboratively because to operate a pulsilogium requires the co-operation of others. We observed the children planning how they would adjust the length of the pendulum whilst it was in motion, organising different roles for members of the group, choosing a satisfactory scale for the instrument, deciding who would determine that the pulse and pendulum were synchronised. Throughout this activity, the children were using science vocabulary to explain to each other when the pendulum needed to be made longer or shorter, to suggest and consider improvements to their methodology and to compare their pulse readings. We also noticed that, as the children started using the pulsilogium, they started asking more questions (as described in 'Testing reliability'), an important skill to foster for practising scientists (Vale, 2013). We suggest that all these experiences will help children to develop scientific literacy: to appreciate and understand the impact of science and technology on everyday life; to take informed personal decisions about things that involve science; and to take part confidently in discussions with others about issues involving science (Nuffield Foundation, 2019).

There are strong arguments in favour of inquiry-based teaching: increased student engagement and deeper understanding of science concepts (Mercer *et al*, 2009) and improvements in student achievement (Blanchard *et al*, 2010; Minner *et al*, 2010; Hmelo-Silver *et al*, 2006). In contrast, the PISA survey of science literacy in 15 year-olds suggested that teacher-directed instruction may be associated with higher student achievement (OECD, 2018), and other reports have suggested that 'minimally guided instruction' is less effective and less efficient than more direct instructional approaches (Kirschner *et al*, 2006). It should be noted that the work of Kirschner *et al* (2006) has been challenged by a number of researchers (e.g. Hmelo-Silver *et al*, 2007), but the consensus is that some scaffolding is required to produce effective results. In addition, it has been suggested that practical inquiries in the classroom do not always include time for reflection and discussion (Osborne & Miller, 2017). At every stage of these pulsilogium investigations, children were encouraged to reflect on their learning; to justify their ideas on the purpose of the pulsilogium in the initial discussion; to consider the merits of different units of measure in the development of a model pulsilogium; and to evaluate the reliability of the 17th century instrument and modern instruments when measuring pulse. We believe that working through these investigations will have a positive impact on children's practical science skills and scientific literacy because, at several stages, the children are encouraged to justify their ideas, consider the ideas of others and revise their initial thoughts (Appleton, 2002).

The series of investigations we have described provide opportunities to explore several types of inquiry (e.g. Appleton, 2002; Turner *et al*, 2011). By asking children 'Which is best?' when considering scales and units, the children experience comparative testing. By asking 'What happens when… you repeat your pulse reading?' or 'What happens when…the patient has rested/exercised before the reading?', the children are required to make observations. Towards the end of the series of pulsilogium investigations, we suggest other activities that children could carry out with a pendulum: changing the mass of the pendulum bob or the arc of the pendulum oscillation. Both investigations are pattern-seeking. We also suggest asking 'Where else is a pendulum used?' and finding out more about digital methods to measure pulse – these require research from secondary sources. The project also includes many opportunities for problem-solving by asking 'How can we…?' questions such as: 'How can we change the pendulum speed whilst in motion?', 'How can we know when the pendulum and pulse are synchronised?' and 'How can we be sure the instrument is reliable?'.

Our second aim was to help children to understand measurement: What is measurement for? What does the measured value tell us? Is the measurement reliable? Giving the children the freedom to choose a scale for their own pulsilogium encouraged them to think about what the numbers or words on the scale mean. They understood the principle of an 'indirect' measurement of pulse taken from a number on the pulsilogium beam, which has nothing to do with a pulse rate, though this was challenging for some adults. The children developed skills of measuring and gathering data and acquired a deeper understanding of measure, because they considered the types of scales and units appropriate for the measurement before they collected their data and had no hesitation in introducing novel scales (see the children's comments that we documented in 'Choosing a scale for the pulsilogium'). The children observed that different scales on different instruments produced different measurements, but became aware that what was important was whether the measurement could be repeated.

We hoped that following the work of a real scientist (though from a very different era) would show children how one scientist approached a problem and tried to solve it. The skills that Santorio exhibited are not very different from those a scientist needs today, or the ones that the children experienced in the classroom: they start with some knowledge, they become aware of a problem, they ask a question, they do something (usually practical) to gather data that provide evidence to resolve the problem and, consequently, they acquire some new knowledge.

The practical stage can be very time-consuming and repetitive and sometimes the new knowledge reveals a new question, leading to more practical work. We believe that the children working on this project deepened their understanding of the repetitive and problematic nature of scientific research and development. They realised that the research process can be slow, that they needed to repeat their results to be sure of reliability and that this could be quite a dull process, but a necessary one. They also became aware that teamwork is important to make progress.

Lastly, we hoped that children would reflect on the value of old technology. The children were excited that their pulse readings were similar when they repeated the measuring process with the pulsilogium (Figure 5) and that a digital metronome synchronised to the pulsilogium also repeatedly produced the same readings on the scale (Figure 6). They were surprised when the pulse meters took time to settle and sometimes produced different pulse rate readings for the same resting patient. Although the children did not repeat any individual's pulse reading more than twice, it was enough to see that measuring and collecting data using an old technology was reproducible.

The history of the pulsilogium and its methodology could be developed further. It offers teachers opportunities to develop a range of cross-curricular topics: for example, to develop a general topic on 'time' (comparing modern clocks with the pulsilogium as a device to measure time), or health, or designing machines. Within any of these topics, teaching and learning could include history, geography, Design Technology (DT) and maths. Questions that pupils could investigate in science are: What did scientists know at the time of Santorio? What did other scientists try to find out? What were the limitations of science research in the 17th century? In geography, the focus could be on Italy or looking at other cultures and countries that have produced famous scientists. In DT, pupils could design, make and compare different pulsilogia and, in maths, they could investigate different units of scales.

Conclusions

Learning about Santorio's 17th century pulsilogium is not part of any science curriculum, but we believe that, through this series of investigations, children can develop their scientific inquiry skills, improve their scientific literacy and acquire an appreciation of the nature of scientific research. It does support the idea of looking at famous scientists and makes important cross-curricular links.

By following the development of a real scientific instrument, even one from 400 years ago, children experience the repetitive and slow nature of scientific research in a context that is meaningful to them. They develop their inquiry skills by taking on the role of a real scientist: to observe, to ask questions, to suggest answers and ways to test their ideas, to explain their findings and to evaluate their own investigations. Children begin to appreciate that science research is about collecting measurements and checking that they can be repeated. Having this historical context provides engaging opportunities for children to debate and solve problems that were real for a scientist.

Using and developing the pulsilogium enables children to investigate different scales used for comparing measurements. Choosing symbols rather than numerical scales helps children to appreciate that measurements can have non-standard units. Having made up new empirical scales of their own, children become aware that scales are man-made constructs and that they only have meaning if the measurements taken from them are accurate and can be reliably repeated. Looking at alternative units for a scale reminds children that the units of measure that they are familiar with (e.g. metres, kilogrammes and seconds) were established not so long ago and have been a crucial development in science research; establishing international standards for weights and measures allows scientists across the world to make meaningful comparisons between data.

Children may be surprised to discover that an old technology (without electricity or microchips) is possibly a more reliable method of measurement than equivalent modern technologies.

The investigations described have demonstrated that children of primary school age understand the difficulties faced by historical scientists and that they can reason and solve problems in a logical way.

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See Appendix on next page.

Appendix 1

Making a simple pulsilogium

To make a pulsilogium (Figure 7a), we used a wooden batten (4.5 x 1.5 x 90 cm), a piece of D-profile moulding cut to the same width as the batten, 2 m of thread (we found that linen is best because it does not stretch), a small piece of modelling clay for the pendulum bob, a small self-adhesive label to attach to the thread as a marker, a rubber band and a strip of paper for the scale. We cut a slot a few millimetres into the centre of one edge of the D-profile and glued this (PVA glue will work), overlapping the end of the batten as shown in Figures 7b and 7c. The purpose of the D-profile is to raise the thread above the surface of the batten whilst at the same time ensuring unrestricted movement of the thread where it changes direction. A rubber band was wrapped around the other end of the beam to hold one end of the thread in place. The thread was laid along the beam and in the slit in the D-profile. About 30 g of modelling clay was attached to the free end of thread suspended under the D-profile to act as a pendulum bob.

Figure 7a: A simple pulsilogium.

The instrument should be calibrated by adjusting the vertical section of thread so that the distance from the underside of the D profile to centre-mass is around 70 cm. A small self-adhesive label should then be fixed to the horizontal thread halfway along the beam. We found that this puts the marker at the centre of the measurement range for a typical resting heart rate.

Figure 7b: Side view of a simple pulsilogium showing the D-piece and pendulum bob.

Figure 7c: A groove cut in the D-piece holds the pendulum thread.

Experience, Explicitation, Evolution: Processes of learning in a free-choice science museum activity for children up to 6 years of age

● Montserrat Pedreira ● Conxita Márquez

Abstract

Using a qualitative methodology and based on the observations of children in a free-choice activity in a science museum, this research focuses on determining which learning processes take place during these sessions. The learning processes of the activities were analysed based on three phases: Experience, Explicitation and Evolution.

The results obtained indicate that the value of the scientific learning of the activity is found in providing children with direct experience with the material. This also favours the explicitation of their ideas and provides abundant stimuli that can generate the evolution of ideas. However, this evolution requires co-operation from other contexts, and greater continuity.

Keywords: science education, early childhood education, science museums, free-choice learning, natural sciences

Introduction

In January 2011, the Natural Science Museum of Barcelona opened its new building, with a view to offering content for the youngest age groups, thus an exclusive space was reserved for children up to six years of age. The *Niu de ciència* (*Science Nest*) was conceived to offer young children access to the natural assets of the museum based on the child's personal initiative and free exploration.

The activity researched for this article, *Puc tocar?* (*Can I touch?)* is made up of various independent and differentiated proposals that bring children closer to natural materials and instruments

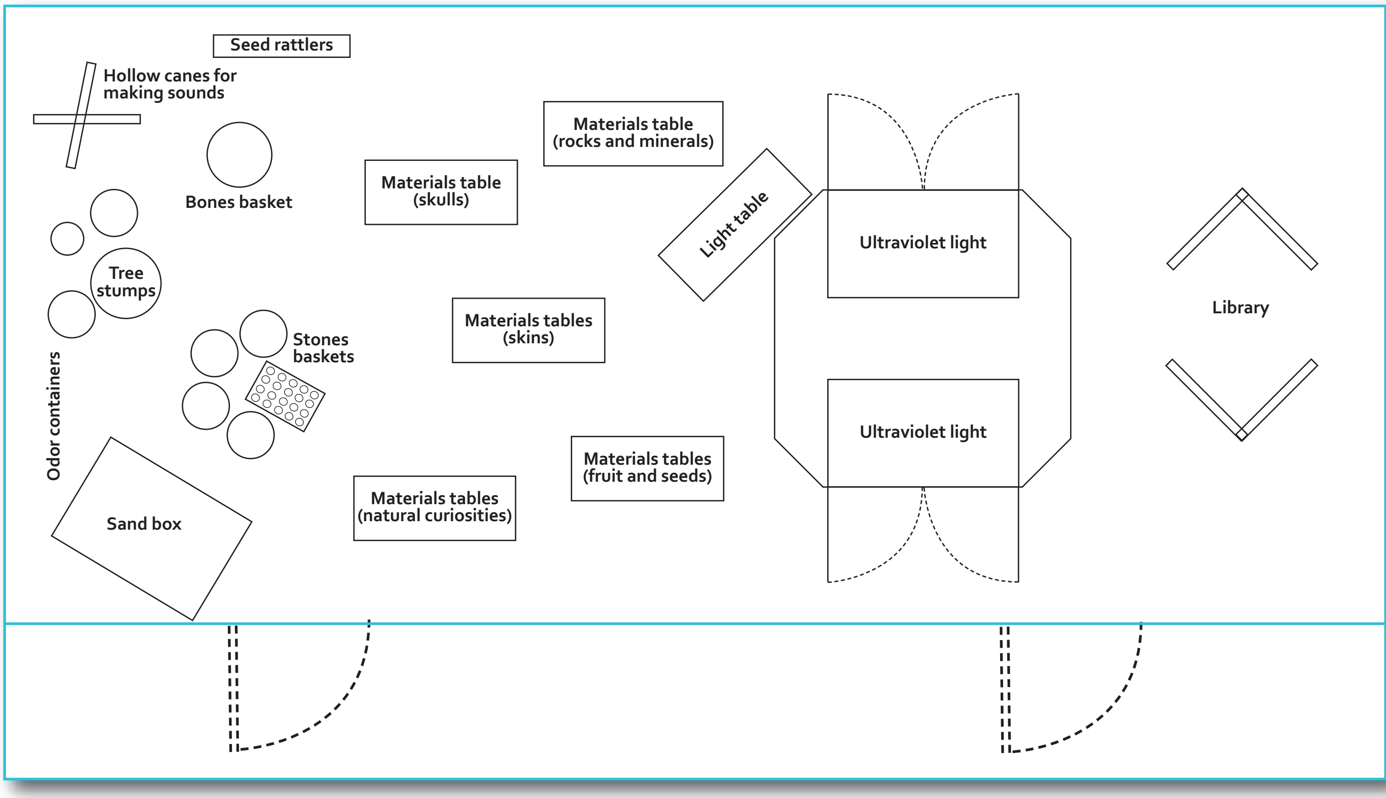


Figure 1: Distribution of the space and materials for the activity *Can I Touch?* (Source: Alba Carbonell, *Niu de ciència).*

inherent to scientific work (magnifying glasses, binocular magnifying glasses, tweezers, etc.). Some of these proposals are X-rays of animals exhibited in a light table; minerals that change colour under ultraviolet light; seeds to be classified using tweezers; collections of natural material (skins, skulls, antlers, shells, stones and minerals, seeds, etc.); seed rings (diversity of colours, sizes, forms, sounds, etc.); a collection of objects from the natural world to be looked at through the binocular magnifier; a large container with sand and remains of animals from the marine environment; and a library with books and tales of science, amongst others. All materials are distributed as shown in Figure 1 on the previous page.

Children had free access to the materials for over half an hour, accompanied by two museum educators who took an active, but not directing, role (Bulunuz, 2013; Kallery & Psillos, 2002). In the *Can I Touch?* activity, the child is the protagonist and the adults must be very careful to consider the relevance of their intervention. They are adults who do not make interventions aimed at the whole group, so that the attention of all the children is not distracted from what they are doing; instead, they directly address children or small groups of children in a discrete voice using the right volume to reach the interlocutors.

Two basic areas of intervention are identified for the adults. On the one hand, educators are an important reference in maintaining a sense of security and as a guarantee of wellbeing for the whole group participating in the visit. On the other, they should be aware to ensure that learning opportunities are provided that do not *'overtake or swamp the ideas of the children but sensitively engage with them as they explore their questions'* (Sands, Carr & Lee, 2012, p.558). In this regard, the role of the educator is not easy.

From the beginning, *Can I Touch?* has been extremely popular among teachers and children, as shown by the evaluations gathered by the museum and the steady increase in demand for the activity from pre-schools. In a prior study, it was found that free choice among high quality natural materials promotes an atmosphere that is both relaxed and stimulating, and propitious for learning (Pedreira & Márquez, 2017). This article focuses on highlighting the learning processes related to science that take place in a free-choice scenario with limited time, such as the one described.

Learning science at the youngest ages

Recent literature (Ferrés, Marbà & Sanmartí, 2015; Minner, Levy & Century, 2010) points to an idea widely shared in science education research that the process most aligned with scientific knowledge, and most interesting from the learning standpoint, is what is called inquiry-based focus (or foci, given the variability). It is a focus that the Natural Science Education Standards (National Academy of Sciences, 1996) define as a process that includes asking oneself questions, planning and carrying out research using instruments and techniques for data gathering, thinking critically and logically about the relationships between evidence and explanations, building and analysing alternative explanations and communicating scientific reasoning. This idea has been qualified in recent publications to put scientific practice at the centre of teaching and learning (Garrido & Simarro, 2014; Monteira & Jiménez-Aleixandre, 2015; Osborne, 2014), so that a transition is made from the concept of teaching science as 'inquiry' to one of teaching it as 'practice'. This scientific practice includes the processes of inquiry, reasoning and explanation based on models (Osborne, 2014).

A review of different authors from several research traditions from different countries on how scientific learning takes place makes it possible to identify regularities or phases with a certain homogeneity that can be observed by reading the vertical axis of the table (Table 1 overleaf).

The first phase focuses on the acquisition of direct experience with reality. Physical contact activities, direct action over the natural world, investigating into the tangible world…different names to highlight the importance of the experience lived out, of contact with reality as a source of primary information, as a base from which to ask oneself questions or launch investigations.

A second phase focuses on the value of language as an individual's expression of the ways of thinking. Certain authors place greater emphasis on pre-existing ideas that will be the basis for the construction of new ideas, while others underscore the communicative process itself.

Table 1: Phases of the science learning process according to various authors.

Osborne (2014)	Researching the tangible world: observing, measuring, gathering data, etc.	Generating hypotheses: developing explanations based on what's been observed.	Evaluating: based on the evidence, data, theories and models.
Harlen (2010)	Direct physical action on objects and materials.	Language as a basis for building abstract ideas.	From specific ideas to the 'big ideas' on science and the construction of scientific knowledge.
Pujol (2003) **Sanmarti** (2006)	Doing: perceiving, observing, handling, monitoring the phenomenon...	Communicating: putting it into words, describing, finding explanations, reasoning.	Thinking: asking oneself questions, imagining solutions, predicting, portraying, modelling, evaluating.
Arcà & Mazzoli (1990)	Experience: doing, working with one's hands, sensibility, perception.	Language: speaking, specifying what experience and perception have made accessible.	Knowledge: the ongoing exchange between language and experience builds individual knowledge that in turn feeds off socialised 'culture'.
Saçkes (2014)	Physical contact activities.	Starting from pre-existing ideas.	Reaching shared discussions to give meaning to the facts.

The third phase focuses on high-level cognitive skills: reviewing, evaluating, building 'big ideas', modelling, predicting, portraying, etc. These are processes whose purpose is to achieve a reasoned change in individuals' ways of thinking – in other words, to achieve learning.

This reiterated organisation in three phases suggests the possibility that the analysis in the *Can I Touch?* activity can be carried out based on a parallel approach, although certain specific aspects should be considered.

Specific aspects of *Can I Touch?*

An initial condition is the age of the subjects, from two to six years of age. They are in development, with limited mastery of language and pre-operational thought (Piaget & Inhelder, 1969).

Another condition is time. The approximate duration of a session, around half an hour, is a significant limiting factor. It must be remembered that participating in *Can I Touch*? can promote other learning opportunities beyond the museum, but the research presented is solely focused on specific aspects that occurred during the visits.

Lastly, it seems relevant to emphasise that the type of materials in *Can I Touch?* are fixed in a natural science museum; this does not allow for experimentation, understood as the direct intervention in materials to intentionally modify them (Pedreira, 2006; Poddiakov, 2011; Sanmartí, Márquez & García, 2002), as this possibility is not offered. Attempts to answer the questions that emerge during the sessions can only be made *in situ* through a process of searching for explanations by interacting with others and/or consulting books or visiting the adult museum.

Specification of the research problem

The research discussed in this article aims to determine which scientific learning processes are promoted in a visit to *Can I Touch?*

To answer this question, two goals are addressed:

- Goal 1: To define the type of analysis needed to evaluate the scientific learning processes; and
- Goal 2: To identify evidence of the scientific learning processes in *Can I Touch?*

Methodology

This research is based on a qualitative methodology, as what is intended is in-depth understanding of educational phenomena, transformation of practice, and decision-making (Sandín, 2003), as well as emphasising the meaning that individuals give their own realities, which provides the phenomena with depth and interpretative richness (Sabariego, 2004). It was decided to conduct a case study, as what was intended was a systematic, in-depth examination of a unique phenomenon or educational entity (Bisquerra, 2004).

An essentially inductive research strategy has been used, in which work is done based on flexible, open guidelines that are adapted depending on what occurs over the course of the research.

Lastly, analysis within the natural context was decided. Despite the drawback of impeding the isolation or control of variables, this has the advantage that comes with the richness and complexity of real situations.

The data in this research were gathered from the observation of three school sessions in the *Can I Touch?* activity, participated in by three different schools from Barcelona province, and covering the range of ages to which the activity is geared (Table 2)

For the analysis of the data, units have been established based on the logical sequence of action, understood as that set of acts that follow a single line of logic, a narrative unit that takes place with certain players, intentionality, and with a beginning and an end.

To complete the data, a focus group was held with the teachers responsible for the participating groups, and a survey conducted among the museum educators responsible for the activity.

To address ethical issues related to the research, a consent form and an information sheet were provided to responsible adults, with the commitment to make no further use outside of academia. Pseudonyms replaced the name of participants.

Results and discussion

Goal 1: To define the type of analysis to evaluate the scientific learning processes

Considering the contributions from research, specificities discussed and based on the observation of the children's behaviour in the sessions established an analysis of the learning processes that might take place in the *Can I Touch?* activities. This is based on a three-phase organisation, parallel to that presented in Table 1.

Age	Date	Duration	Number of children	Number of sequences identified
2 year-olds	February 27, 2014	42 minutes	22	60
4 year-olds	September 27, 2013	27 minutes	13	59
3, 4 and 5 year-olds	April 4, 2014	30 minutes	12	143

Table 2: Basic data on observations made, ordered by age of the children.

The three phases are entitled *Experience*, *Explicitation* and *Evolution.* Their justification follows:

❒ Experience

If the subjects are children of the youngest ages, apprentices to the world, it seems logical to attach more relevance to an initial phase, experience, which is based on gathering information from contact with reality. The observation of the sessions made evident three different types of actions focused on gaining experience:

- *Use of the senses:* this is an especially relevant aspect of the *Can I Touch?* activities given the sensory wealth in colours, shapes, textures, weights, sounds, smells, etc. of the natural material, but also because early childhood is a stage in which sensory information is recognised as being very important by authors of classical pedagogy (Montessori, 1972), by the science museum realm (Dierking, 1991; Falk & Dierking, 2000) and by the contributions from neuroscience (Mora, 2013). Therefore, in the analysis of the activity, situations are sought in which it is identified that the senses are being used in an intentional way.
- *Exploratory actions:* understood as *'action sequences that respond to the interests of the child, who organizes and structures them autonomously, the result of which is the attainment of information on the object or phenomenon'* (Weissmann, 2014, p.31). Authors such as Poddiakov (2011), who appreciate natural objects as activators of the development of exploratory activity, also refer to the importance of children's activities to actively understand the world based on their own actions. Other such authors include Sands, Carr and Lee (2012) who state that one of the ways in which research is developed in children is through dialogue between them and the objects, often without spoken language as a mediator and only through direct action.
- *Use of instruments:* the importance of instruments as cultural mediators and the need for them to build scientific facts is addressed by several authors (Falk & Dierking, 2000; Izquierdo, 2006; Sanmartí *et al*, 2002). In *Can I Touch*?, children are given access to magnifying glasses, binocular magnifying glasses, strainers or tweezers. Within the research process, the occasions when the children made exploratory use of these were observed. In other words, observations took place when it was clear that the children intended to make scientific use of the instrument, either correctly (for example, keeping the right distance between the magnifying glass and the eye) or, if they were just trying it out, trying to find the right way to use it.

❒ Explicitation

The second phase emphasises the showing of children's pre-existing ideas, which must be used for the construction of new ideas. To do so, we rely on the one hand on communicative processes, because when something is given a name, when it is defined or explained, this is done based on the existing theories about the world (Gómez, 1998), but also with the operations related to the formation of concepts (Jorba, 1998; Kamii & DeVries, 1978; Piaget, 1964), such as comparing or classifying, as basic cognitive skills through which information is structured. Most of the material in *Can I Touch?* are collections (of stones, skins, skulls, antlers, etc.) that are presented, grouped with the idea of helping children 'group the things that go together', identifying the qualities that are shared among all the elements of the collection while also pointing out what sets them apart. Arcà, Guidoni and Mazzoli (1990) stress the importance of underscoring similarities and differences as a gateway to conceptualisation.

Harlen (2010) states that experience gradually brings about the construction of abstract ideas, and that grouping and classifying by different criteria lead to the development of concepts. Zohar (2006) advocates the value of actions such as comparing or classifying, which she defines as activities of a higher order, given the fact that the formation of concepts is an act not only of perception but also one that is intimately related to the use of a theoretical reference model.

Recognising 'what goes together' can be done with or without words and, given the age of the subjects of this research, especially in the case of the youngest children, it makes sense to take into account and evaluate the actions by which children specify what they think, while also considering the linguistic skills that make it possible to share their thoughts. With a view to integrating both processes, the cognitive and communicative, which are so intimately linked, the suggestion of Inan, Trundle and Kantor (2010) was followed. They emphasised the value of labelling information with a name that has a meaning shared with others (naming), indicating similarities and differences (comparing), organising the information into significant units based on comparison (classifying) and sharing this information with others (communicating). In the latter category, based on the contributions of several authors (Jorba, Gómez & Prats, 1998; Naylor, Keogh & Downing, 2007) and taking into account the observations recorded, two specific cognitive-linguistic skills have been considered: describing and reasoning. Regarding the latter, it should be noted that, at such young ages, it is not meant to find complete reasoning with the need for acceptability, belonging, completeness and precision, but that the cases in which the child contributes some explanation on the object or phenomenon are identified.

❒ Evolution

Understanding learning as change (Pozo, 2008) means attributing value to the evolution of children's ideas, which is manifested in two ways in *Can I Touch?*

- *Emergence of questions:* this is determined by all authors to be a fundamental step to approach any problem, and a significant first step to consider the possibility of changing ways of thinking. Mora (2013) states that anything that is different and stands out from its surroundings sparks excitement and, with that, the windows of attention are opened in a focus necessary for the creation of knowledge.

  Csikszentmihalyi and Hermanson (2009) propose a learning paradigm in museums that begins with the need to attract the subject's attention (the 'hook') and is based on curiosity (probability of investing mental energy in a new stimulus) to reach the interest (probability of investing mental energy in one stimuli more than others). It is the same idea that Wagensberg postulates (2008, p.24), when he highlights the importance of the '*stimulus, that is useful to go from one mood – in which an individual is not especially interested in knowing anything specific – to another, in which they do seek to know something, even with urgency'.*

  Considering the age of the children, not only their specific questions but also the statements or actions to which adults can give the value of a hypothesis have been considered to help question ideas and facilitate the possibility of change.

- *Introduction of new knowledge:* understanding learning as change means attaching value to the entry of new ideas as a basic factor to achieve a change in pre-existing ideas. Situations in which children's ideas are reconsidered, as related to the contribution of new information, are taken into account. Three ways of introducing new ideas were identified: by direct contributions from the adult; triggering the contrast of ideas among peers; and also the consultation of books.

Table 3 on page 25 sums up the categories of analysis identified based on the alignment between the existing literature on science learning at the youngest ages and the observations made in *Can I Touch?*

Goal 2: Identify evidence of scientific learning processes in Can I Touch?

After finishing the definition of the categories, their application in the observed sessions was necessary. To do so, all appearances of each category in each sequence were tallied up. To compare the data from session to session, the number of appearances was divided by the total of sequences in each session, resulting in a frequency of around 1.

An example of the identification of each of the categories in the sequences is shown in Table 4 on page 26.

❒ Experience

Figure 2 on page 27 shows the comparison among frequencies of appearance of each experience phase categories in the different sessions, corresponding to different ages.

The frequency of opportunities to acquire direct experience with reality through the three highlighted categories is clearly high – 1.68 overall. This is proof of one of the values of the activity.

Table 3: Analysis categories of the science learning process in *Can I Touch?*

EXPERIENCE with reality	Use of the senses	Looking Touching Listening Smelling
	Exploratory actions	Picking up, putting down Shaking Filling-emptying Tapping Fitting into Passing on Building towers
	Exploratory use of instruments	Hand-held magnifying glass Binocular magnifying glasses Strainers Tweezers
EXPLICITATION of children's ideas	Cognitive-linguistic	Naming Comparing Classifying Describing Reasoning
EVOLUTION of children's ideas	Emergence of questions	As questions As statements As actions
	Introduction of new knowledge	Contributions from the adult Contrasting of ideas between peers Consulting books

The results are irregularly distributed within each category. Looking and touching are by far the two most used 'sense actions'. Shaking, fitting into and passing on are the most recurrent exploratory actions. Hand-held magnifying glasses are the instruments that generate the most interest and activity.

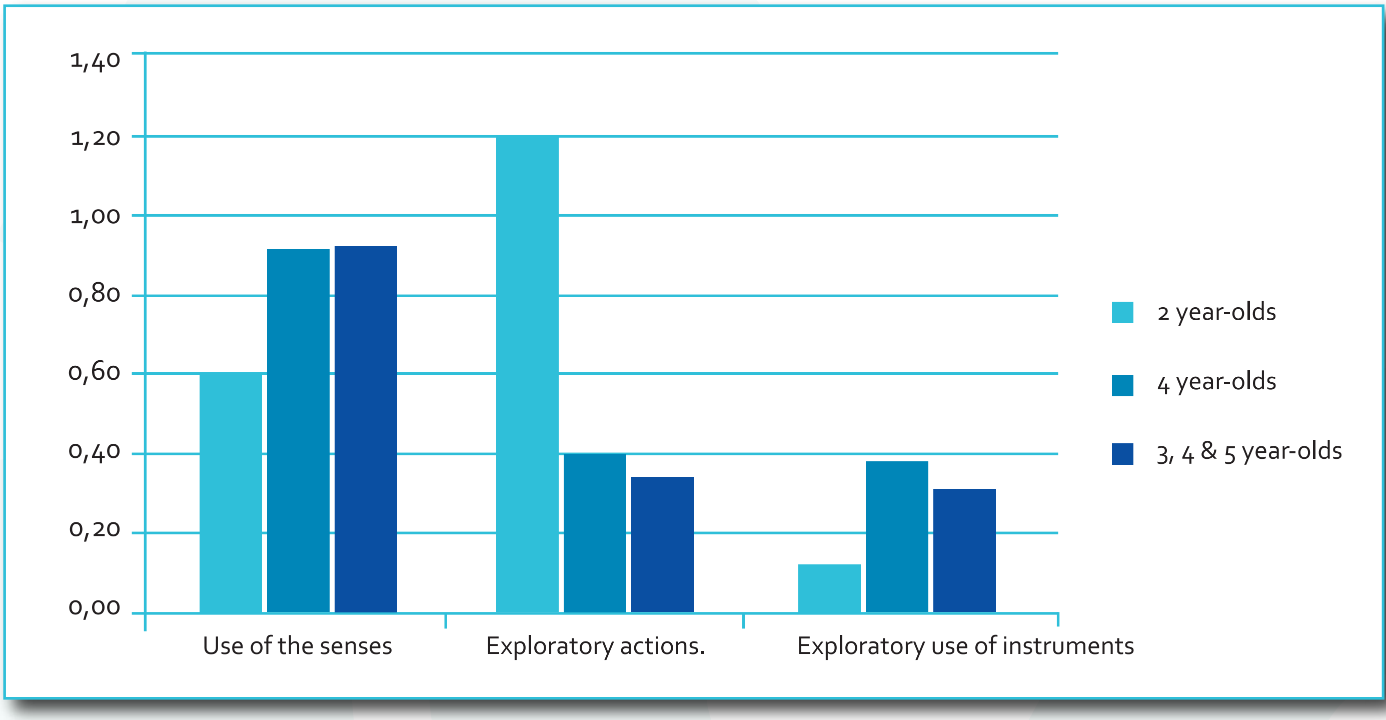
Some observations, such as the use of specific instruments like hand-held and binocular magnifying glasses as observation instruments appearing to increase the frequency of use of the senses, suggest the possibility of introducing modifications in the design and presentation of the materials to achieve results more in line with what is intended.

By ages, the high value of the exploratory actions in the case of the 2 year-olds studied is noteworthy. This coincides with the behaviour descriptions for this age made by various authors (Kamii & DeVries, 1978; Quintanilla, Orellana & Daza, 2011; Weissmann, 1999). Compared to older children, this age group shows little activity in the use of instruments.

Table 4: Sequences from each category for analysis of the science learning process in *Can I Touch?*

EXPERIENCE with reality	
Use of the senses / Touching 2 year-olds	31:26 (...) The girl answers, **and lies down over the skins again and begins to touch two skins with both hands**. The adult leaves. **The girl touches the skins a little while longer.** Then she gets up and goes to the stones table, where there are several children. 31:50
Exploratory actions / Shaking 2 year-olds	14:27 Rattles are heard. **There is a boy next to the panels shaking a rattle with each hand. A girl approaches, takes one in each hand and shakes them.** They look at each other. The girl leaves both rattles on the floor and leaves. (...) 14:50
Exploratory use of instruments / hand-held magnifying glass 4 year-olds	6:01 **A boy approaches the magnifying glass table and picks up the cylindrical magnifying glass. He brings it close to his eyes, backwards. He turns it, and looks again.** Then he puts it down and leaves. 6:15
EXPLICITATION of children's ideas	
Cognitive-linguistic / reasoning 4 year-olds	3:50 (...) Teacher: Creatures, from where? She retraces the X-ray of the snake. She stops and shrugs her shoulders as if to say, 'I don't know.' She looks at the camera. Teacher: Are they all the same? Child 14: No Teacher: Oh? They aren't? Child 14: **No, because this one is smaller and this one is bigger (comparing the two snake X-rays. He touches them with his hands). And these (the small snake and the lizard) look the same, but they aren't.** (...) 4:47
EVOLUTION of children's ideas	
Emergence of questions / As actions 4 year-olds	0:00 (...) The boy goes to pick up a skull. There are four children speaking while holding skulls in their hands. **Another child goes to the horse skull, and opens and closes the jaw. He takes a tooth from the box and tries to fit it into the lower jaw.** A boy picks up a skull and places it on his head. **Boy: I put it on here!** He puts the skull back in its place, picks up another one, and looks at it. (...) 1:05
Introduction of new knowledge / Contrasting of ideas among peers 3, 4 and 5 year-olds	11:16 (...) Educator 5: What do you think this is, [Boy 8]? Boy 8: Skin. **Educator 5: [Girl 4] says that it is from a snake.** Girl 4: And that it is skin, too. Educator 5: It is snakeskin, says Girl 4. The boy leaves. Girl 4 tries to open the cylinder. Educator 5 takes it from her, apparently to open it for her.

Figure 2: Frequency of appearance of each experience phase category over the various sessions.



❐ Explicitation

Figure 3 shows the frequencies of appearance of the explicitation phase categories.

Once again, the distribution is shown to be very irregular. Some of the categories show high frequencies, such as 'naming' and 'describing', while 'comparing', 'classifying' and 'reasoning' appear on very few occasions. This is apparently attributable to the fact that, as Zohar (2006) states, they are demands of the highest cognitive level.

The data evidence a relationship between explicitation of children's ideas and their age.

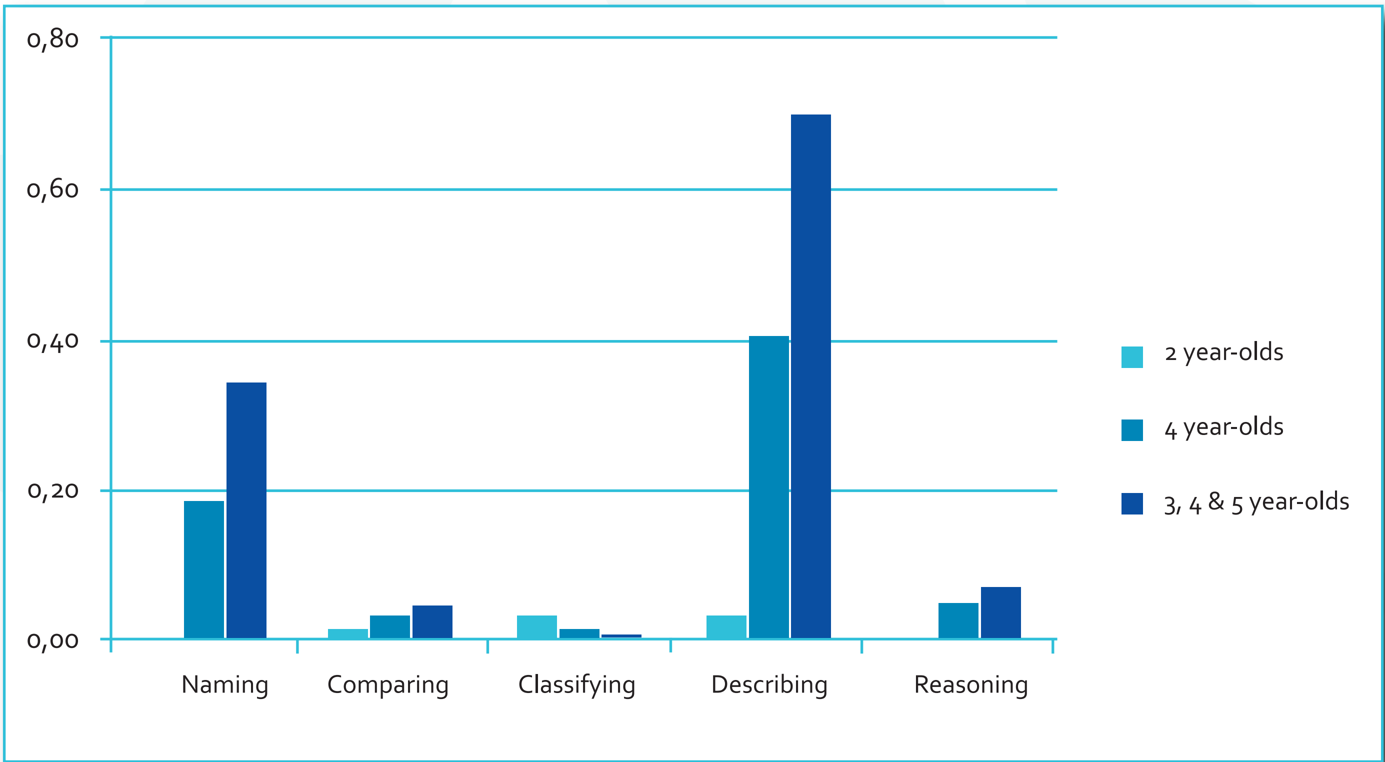


Figure 3: Frequency of appearance of each explicitation phase category over the various sessions.

As it is an area closely related to language, logically, the group of the youngest age has the lowest frequencies. This suggests the importance of finding ways to favour young children's ideas being made clearer through actions, not just language.

❐ Evolution

Figure 4 shows the frequencies of appearance of the evolution phase categories.

The graph shows a notable difference between the frequency with which questions emerge and the introduction of new ideas. This suggests that the visit to *Can I Touch?* favours starting points for the emergence of curiosity that can lead to inquiry itineraries, but does not promote the introduction of new ideas.

In an analysis by age, the idea of a revision phase seems out of reach for the youngest children. Although this seems logical, as it is related to a higher level of cognitive development, it must also be remembered that it is largely evaluated based on language. Although the research confirmed the possibility of identifying physical actions that have no spoken form as questions asked by children (for example, placing antlers over their heads, on their nose or backs as a reflection of their hypotheses), the difficulty of the adults in recognising them as such was also confirmed.

❐ Overall results of the three phases

The distribution of frequencies by phases and ages is reflected in the graph on the following page.

Figure 5 shows that the essential strong point of *Can I Touch?* is made up of the possibilities provided by acquiring direct experience with reality at all ages, but most especially in the youngest children. The activity also facilitates, although to a lesser degree and mostly in children of three years of age, the explicitation of their ideas. As regards the evolution phase, points of curiosity are generated that can then give rise to a process of change in ways of thinking.

Conclusions

Goal 1: To define the type of analysis to evaluate the scientific learning processes

Research into science learning for children of young ages and in the context of isolated sessions in a museum makes it necessary to adapt the type of research used with adults.

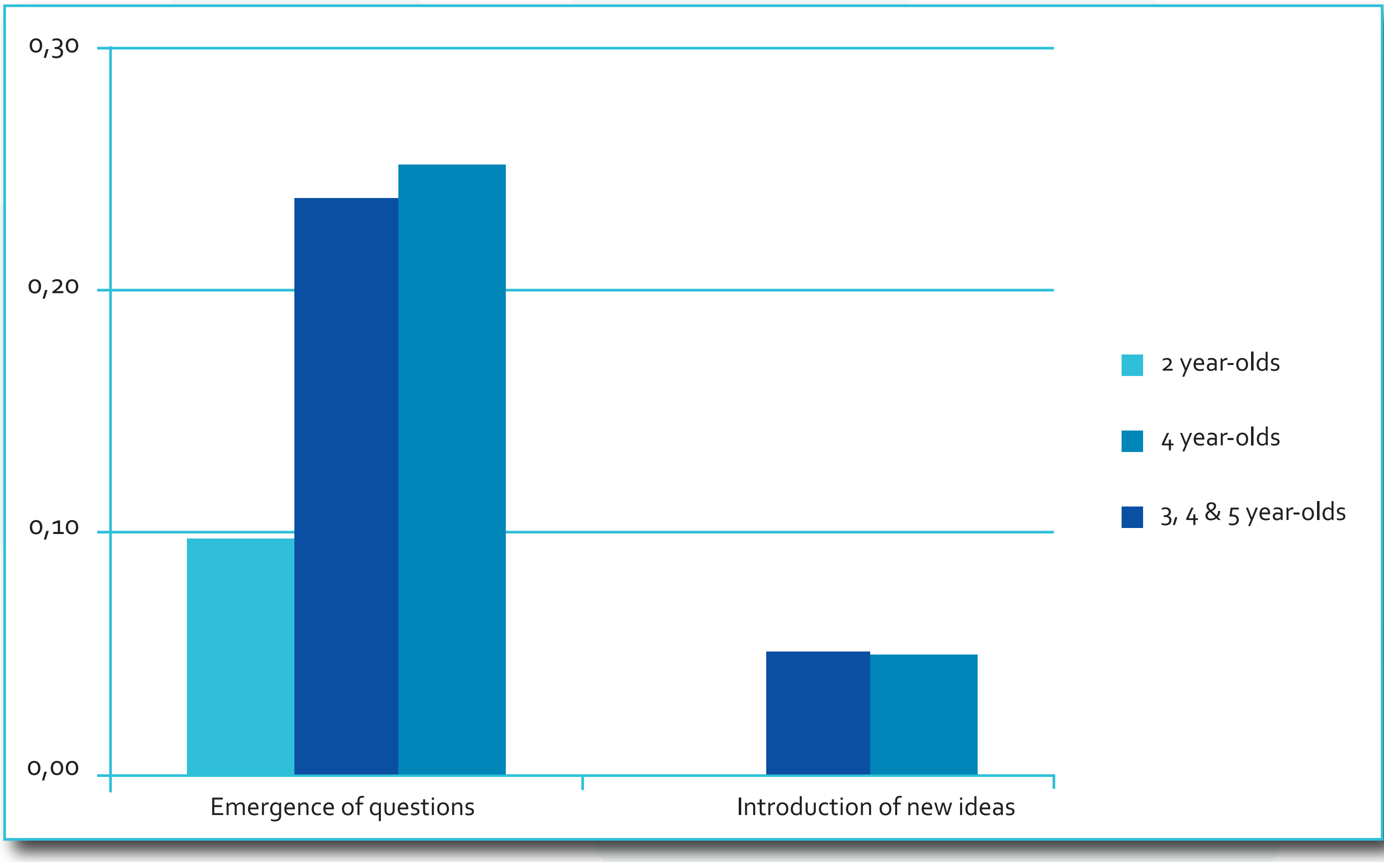
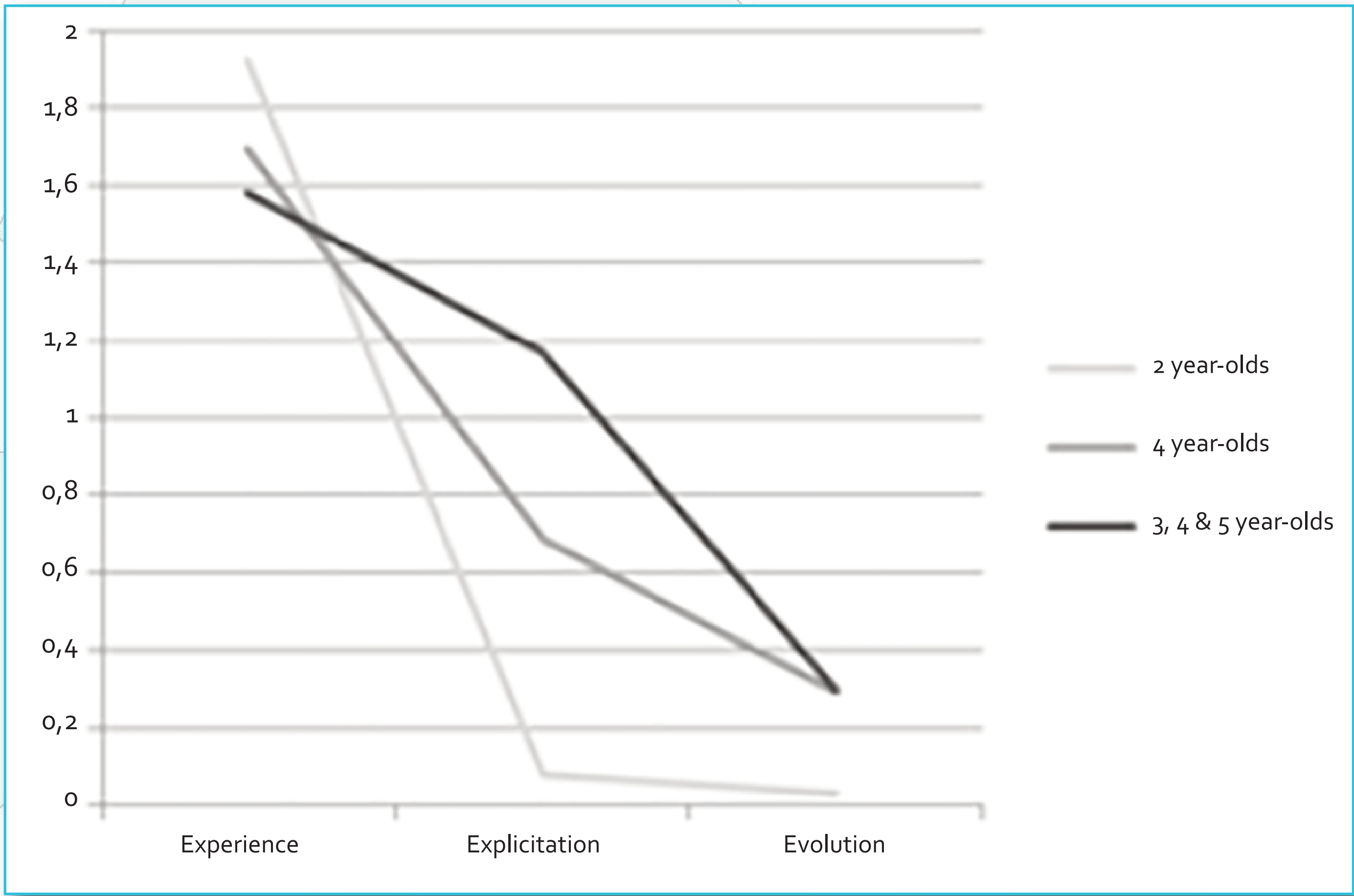


Figure 4: Frequency of appearance of each evolution phase category over the various sessions.

Figure 5: Overall frequencies of the 3 phases by age groups.



The definition achieved in this study for the specific case of the educational activity *Can I Touch?* proposes phases that are parallel to those used with adults, but bearing in mind specificities: an activity aimed at children of the youngest ages, of limited duration over time and restricted to natural sciences.

The structure of the three phases, *Experience*, *Explicitation* and *Evolution*, is proposed as a groundwork to face the analysis of learning processes in a free-choice science learning activity, and for the youngest ages. The three phases are likewise divided into categories (see Table 3 for the case of *Can I Touch?*) that can be expanded or modified depending on the specific case in which the analysis is to be applied.

Goal 2: To identify evidence of scientific learning processes in Can I Touch?

Applying analysis based on the three phases, *Experience*, *Explicitation* and *Evolution*, as has been explained and justified throughout the text, defines *Can I Touch?* as an activity of great educational value. It is valuable because it provides direct experience of contact with natural material, it facilitates the explicitation of children's ideas, although irregularly, and it allows the emergence of curiosities that can be starting points for inquiry itineraries.

In research with adults, great emphasis is placed on the phase of greatest abstraction, incorporating processes such as modelling or evaluation, which have not been observed in the free-choice situation analysed. Considering that the children only had half-an-hour of autonomous exploration, it seems logical that no evolution is observed in their ideas, beyond momentary contributions. On another note, it seems that the activity offers important possibilities as a generator of stimuli (emergence of questions), which can be an important first step to initiate inquiry processes that will require continuity in other contexts. Given the fact that these are school visits, the most appropriate course of action should be the school itself, following the ideas of Kisiel (2005), Guisasola (2013) or Viladot (2015), who suggested integrating the visit to the museum as part of the class planning to obtain learning results that can involve aspects such as discussion about facts, modelling, or the evaluation of new ideas.

Like any research process, this one concludes by opening up new questions: would more evidence of the idea of evolution be generated in a free-choice school context in which, as opposed to the museum, children have sufficient time to take part in experiences with continuity? Can the environment be modified (inquiries, organisation, the role of the adult) to increase the occasions in which evidence of idea evolution is produced?

Lastly, it is relevant to note that two of the three schools participating in the research introduced changes in their classrooms following the visit to the museum, incorporating natural materials and various scientific instruments, and generating awareness about the value of getting questions to arise in children over teaching them the answers. This suggests the possibility of informal education being an element with which to streamline educational change in formal education. This shows the importance of reflection and pedagogical research set outside the classroom.

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Challenging stereotypical images of science: Suggestions for the reading of science trade books* in the early years

● Lena Hansson ● Lotta Leden

Abstract

Previous research in science education shows that science and scientists are frequently described in stereotypical ways. Stereotypical images of science and scientists can be found in science teaching as well as in different forms of media and children's books. In this article, we suggest scaffolding themes and topics for discussion when reading science trade books to children. These suggestions can help in directing children's attention towards different issues related to Nature of Science (NOS). Concrete examples from science trade books are discussed with the aim of providing ideas for how stereotypical images of science and scientists can be challenged as soon as from early childhood education.

* *The definition of the term 'trade books' in this article is: 'books published for the general public and not primarily aimed to be used as educational material'.*

Keywords: Emergent science, nature of science, scientists, stereotypical images, trade books

Introduction

Science education research emphasises the importance of not only focusing on specific science phenomena in the teaching of science, but also on the Nature of Science (NOS) (Allchin, 2011; Leden *et al*, 2015; Erduran & Dagher, 2014; Lederman, 2007; McComas, 2017). To include NOS perspectives means challenging a tradition that has mainly focused on ready-made facts, and instead also deals with issues such as: *What processes have led to science knowledge (facts)? What is the relation between empirical data and theoretical reasoning? How do human elements influence science? Are there limits to science or will science be able to answer all kinds of questions?* The inclusion of such issues can enhance children's interest and enjoyment in science and science education (Aikenhead, 2006; Allchin, 2014; Clough & Olson, 2012; McComas, 1998) and provide a basis for increased scientific literacy (Allchin, 2014; Driver *et al*, 1996; Hodson, 2008; 2009).

Previous research shows that stereotypical images of science and scientists are common in school science as well as in different forms of media. Stereotypical images can also be found in media aimed at young children, such as picture books and television programmes. One example of a stereotypical image is when scientific knowledge is presented as indisputable facts, without mentioning the knowledge processes and the scientists involved. When scientists are mentioned, they are often pictured in stereotypical ways. Further, stereotypical images of scientists are frequently expressed among children in, for example, their drawings (Barman, 1999; Finson, 2002; Rodari, 2007). Such drawings, by children of all ages, often show images of the scientist as a white lab-coated man who wears glasses and carries a test tube.

One way in which young children meet science is through science trade books (books published for the general public and not primarily aimed to be used as educational material). For the youngest children, these books take the form of picture books. NOS is often not addressed in an explicit way in such books. A study by Schroeder *et al* (2009) shows that only 21% of the 116 science trade books aimed at 8 year-olds analysed addressed NOS. Similarly, Brunner and Abd-El-Khalick (2017) found that only two of the 50 analysed science trade books aimed at children aged 11 included explicit references to NOS. Furthermore, previous research has shown that children's trade books contain many of the above mentioned stereotypical images of science and scientists (e.g. Dagher & Ford, 2005; Zarnowski & Turkel, 2012). In a recent study of 28 science picture books aimed at elementary students, Kelly (2018) shows that most scientists in books are white males, and that the extent to which NOS is represented varies widely between books. However, the images are sometimes broadened, especially when it comes to books that describe contemporary science. Still, even though books about contemporary scientists' work more often provide detailed descriptions of tools and equipment, or describe scientists who are engaged in collaborations, they often over-emphasise observations and seldom describe how theories are developed (Dagher & Ford, 2005).

It has been suggested that teachers should be provided with tools in order to be able to choose books more wisely (Zarnowski & Turkel, 2012; Ford, 2004) and that teachers need to develop skills to scaffold discussions connected to book reading so that children's images of science and scientists can be broadened (Dagher & Ford, 2005; Sharkawy, 2009; Zarnowski & Turkel, 2012). Most of the above mentioned studies have focused on science and literature in primary and middle school and very few have investigated books for the younger audience. Other studies have focused on the extra textual talk (i.e. discussions) that surrounds book readings (not specifically focused on science) for younger children (e.g. Andersson *et al*, 2012 and Price *et al*, 2009).

This article suggests themes for teachers and children to discuss in connection with the reading of science trade books. The focus is on suggestions for NOS teaching aimed at the youngest children (aged 1 to 9 years). Since picture trade books are a common way through which young children are exposed to scientific knowledge, the images of NOS in these books need to be scrutinised and strategies developed to challenge stereotypical images when they appear. Furthermore, this article suggests ways to focus on NOS issues suitable for the youngest children, since most of the research in this area has focused on older students (Akerson *et al*, 2010; Bell & Clair, 2015).

Design of the study

As discussed above, NOS is most often implicit in science trade books and, when NOS-related issues *are* mentioned, this is frequently done in stereotypical ways. In this article we elaborate on suggestions for how teachers might direct attention to different NOS issues in connection to the reading of science trade books *and*, when necessary, how to problematise the images provided in the books.

The research literature provides different suggestions concerning what NOS aspects to address in the teaching of science (Erduran & Dagher, 2014; Lederman, 2007; McComas, 2017). Despite taking a different focus, all frameworks highlight: characteristics of scientific knowledge (e.g. that it is open for change, and has limitations); how scientific knowledge is developed (e.g. the central role of empirical work); and science as a human activity (e.g. creativity and subjectivity is part of the scientific processes). In this article, we have used the overarching themes: *Scientific knowledge*; *Scientific processes*; and *Scientists* to organise the suggestions of NOS themes. These themes were inspired by the three categories described in McComas (2017): 'Science knowledge and its limits', 'Tools and products of science' and 'Human aspects of science'.

Our suggestions for how to direct attention towards NOS take science picture books as starting points. The excerpts are chosen from a collection of picture trade books (n=36) aimed at young children (ages 1 to 9 years). The books were not chosen as a representative collection, but rather aimed at including examples of books relating to *different* science areas (astronomy, biology, chemistry, geology, physics), as well as representing different genres (non-fiction and fiction with a content related to science). Thus, the themes we suggest are broad and can be connected to a wide range of issues common in children's trade books. All books mentioned in this article are published in Swedish (sometimes translated to Swedish from other languages). All excerpts from the books have been translated from Swedish into English by the authors of this article. The excerpts are labelled according to the target group, based on our own evaluation and the evaluation from online bookstores.

Suggestions of NOS topics in connection to book reading

This section illustrates ideas of how images of science and scientists can be broadened through directing attention towards different NOS issues in relation to texts and/or images in the picture trade books. The section is organised around three themes: *Images of scientific knowledge; Images of scientific processes;* and *Images of scientists* and suggests issues to focus on during book readings.

Images of scientific knowledge

Picture trade books often carry messages about scientific knowledge that are in line with the stereotypical and mythical images described above. For example, science knowledge is frequently presented as a bulk of facts and no reference is made to the limitations of science (neither concerning the knowledge we have today, nor concerning the principal scope of science).

Yet, there are examples in the material analysed where these stereotypical images are challenged. One example is a non-fiction book about astronomy (aimed at ages 3 to 6), where the surface of the moon is described as follows: *'This dark surface on the moon is actually not a sea. It is a large plain, but previously astronomers thought that it might be a sea. This was where the first moon rockets landed'* (Martin & Sanders, 2016). This example communicates that scientific knowledge about the moon has changed, and is different today to what it was before. Other examples from non-fiction books communicate that there are still things not known by science: *'We know that dinosaurs had scales. But were dinosaurs grey, green, red or all colours at once? Were they spotted or striped? One wonders…'* (Rolland, 2002, flap book aimed at children aged 3-6).

These two examples illustrate how science knowledge can be communicated as open to change, and limited in meaning, and that science does not have answers to every question. As a way to broaden the image of science, teachers can purposely direct children's attention towards such instances whenever they appear in a book. One way of highlighting uncertainty could also be by emphasising certain words that highlight uncertainty (e.g. 'scientists *believe*'), or changes in scientific knowledge (e.g. '*previously* we thought') and focus the discussion explicitly on uncertainties or changes. Such words are otherwise often lost to the reader (see Ford, 2006 for a discussion on the extent to which children grasp subtly-formulated statements).

However, as previously mentioned, most books only tell *how things are*. In Swedish everyday talk, such books are often labelled as 'fact books'. Some of the books are also titled 'Facts about…'. Facts are presented as statements of how things are. The following is from a book about elephants (aimed at ages 6 to 9 years):

'Elephants talk to each other with very low sound – which we cannot hear' (Maclaine, 2012).

Similarly, in a fiction book (aimed at ages 1 to 5 years), a tree is telling the reader/listener about different animals. In the example below, the tree is telling the listener about squirrels:

'The squirrel is climbing and scratching my neck and looks for the dry mushrooms. Furthest down in a forked branch I can feel a hazelnut that she has forgotten. But, I won't say anything!' (Bengtsson, 2006).

Thus, when these books are read to children, the listeners are exposed to a great deal of knowledge about elephants and squirrels and their ways of living. What is left out, however, is when, how and by whom this knowledge has been developed – the book only tells the reader or listener how things are. When books communicate science as facts, the teacher can pause the reading and start a discussion centred around the issue of how we know these 'facts'. With respect to the books about elephants and squirrels, the teacher can discuss with the children issues such as: *How do we know these things about the life of elephants/squirrels? Have we always known? Who has found out? Are people doing research on the life of elephants/squirrels today?* Raising such issues could lead to discussions about how science knowledge is developed by humans. It could also lead to an interest to learn more about the research process in science (discussed below).

Challenging the notion of 'science-as-facts' can also mean taking opportunities to direct attention to ongoing research, uncertain knowledge, and to principal limits concerning the scientific method in science, even if this is not a topic in the book. Teachers could, for instance, with respect to the multitude of space books aimed at young children, pause their reading and start a discussion on ongoing research, and things into which science does not yet provide insight.

Similarly, considering the following extract from a book about dinosaurs, it is possible for the teacher to challenge the notion of 'science-as-facts'. The extract describes reasons as to why the dinosaurs disappeared:

'Continents drifted apart and weather changed /.../ There were also several eruptions that let out poisonous gases /.../ and as if that was not enough a large stone from space, a meteorite, crashed on earth! /.../ The crash led to earthquakes, tidal waves, and further eruptions' (Sheppard, 2008, aimed at ages 3 to 6 years).

Despite the ongoing discussion in the scientific community about the significance of different explanations (meteors vs. volcanoes), the book presents a collapsed explanation as a 'fact'. Nevertheless, a teacher could use this example to raise the issue of different or conflicting explanations.

Images of scientific processes

When science is communicated as 'facts', the process of science becomes hidden. As exemplified above, books communicate knowledge about, for example, elephants, squirrels, space and dinosaurs without providing any detail concerning the processes that have led to the development of this knowledge.

Yet, one can find examples where scientific processes are highlighted. Such examples are common in non-fiction books about space: *'Scientists at a space station do experiments. They investigate how plants and crystals grow when they are weightless and what happens to small animals like mice and spiders when they are in space'* (Nelson & Harper, 2000, aimed at ages 3 to 6 years).

Here, the teacher can pause the reading and focus on the issues of research questions and processes. Issues for discussion could be: *What are the scientists interested in? Why? How do they investigate this? Do they need some equipment?* Related to the latter question, books do sometimes show examples of tools used by scientists, such as a microscope, telescope, spade, computer, test tube, all of which could be discussed from the points of *why* and *how* scientists use these tools.

The scientific processes that are mentioned in science trade books aimed at young children almost exclusively target empirical aspects of the process of science – it is all about experiments and observations (c.f. Dagher & Ford, 2005). The theoretical aspects of the processes are very seldom mentioned, even though some examples do draw attention to the thinking processes (in the example below, the discoverer in shape of a turtle, Professor Shellback [Swedish: Skalman], is thinking and counting):

'Can you figure out where on the Earth it will land? Shellback was standing quiet with closed eyes /.../ – I am counting, said Shellback, and a minute later, – Now I have figured it out' (Andréasson, 2000, aimed at ages 3 to 6 years).

Similarly, human elements of the research process such as discussions, argumentations or publishing are rarely mentioned (see next section). A way to expand the meaning of scientific processes further could be by posing questions such as: *What do you think the scientists did before the investigation? What do you think they did after the observation?* In this way, the teacher adds to the information provided in the books by directing attention to the theoretical and human elements of the research process.

Images of scientists

Scientists tend to become invisible as a consequence of neglecting the scientific processes in the picture books (see previous section). On the other hand, in books where scientists are visible, there are stereotypical images of scientists as well as instances in which such images are challenged in different ways. Teachers can direct students' attention to non-stereotypical images, such as in the example below where collaboration between different scientists is highlighted:

'A palaeontologist has found bones from a dinosaur in the desert. He removes sand and clay with his tools. To protect the bones he plasters them, just like you do with broken legs. Then, the bones are put in crates and transported, first in a truck and then by aeroplane. Other scientists study the bones and try to figure out what the dinosaur looked like' (Rolland, 2002, flap book aimed at children aged 3 to 6 years).

Trying to emphasise such instances in books could broaden the images of science and scientists that children hold. However, it is important for the teacher to also problematise stereotypical images when they appear in the books. For example, when scientists are only displayed in books as male white scientists, the teacher can ask: *Can everyone become a scientist? Why is it that most pictures in the book show males?* Furthermore, many books contain stereotypical images where scientists are characterised as wearing lab coats and using test tubes, even in science topics where such equipment is seldom used (e.g. astronomy). In such cases, the teacher could ask questions such as: *Do scientists always wear lab coats? Why are they sometimes wearing lab coats? Are scientists normally wearing lab coats when studying the stars?* Similar questions can also be raised in relation to other stereotypes, such as test tubes: *What tools and equipment do scientists need? Is it always the same?* In cases where the books alter and broaden these characteristics, by for instance showing other kinds of outfits and accessories such as cargo pants, pencils and computers, the teacher can take the opportunity and pinpoint these differences.

Highlighting the human element of science also forms part of discussing and problematising the image of scientists. For example, in astronomy books you sometimes find examples of situations where the personal and human needs of astronauts are made evident, e.g. that they need food, rest and leisure time. Other human elements of science, such as creativity and socio-cultural aspects of science, can be harder to find in science trade books. However, by highlighting issues such as *Why are people interested in this? Who pays their salary? Why are the books showing a flag on the moon?*, as well as focusing on what happens before and after the experiment/observation, such aspects of science can be made visible.

Conclusions

A teacher who wants to teach NOS by using science trade books can get some support from the book itself, but often to a rather limited extent. As has been previously discussed, some science trade books challenge the notion of 'science-as-facts' to different extents. If teachers want to problematise stereotypical images of science and scientists, they need to direct the students' attention to these instances in the books, by emphasising certain words or passages or by posing additional questions or making statements: *Look at the astronauts; I wonder how it feels to sleep like that in a space station*.

In almost every case, the teacher also has to add information and/or challenge the already existing information. In some books, the notion of 'science-as-facts' is challenged by showing that scientific knowledge is not just 'there', but has been developed by humans. However, overall, rather simplified images of the science processes are provided. For instance, only strictly empirical parts of the knowledge processes are mentioned, and discussions of theoretical aspects are missing.

In cases when science trade books communicate stereotypical images, the teacher needs strategies to challenge and question them. One way we have suggested in this article is to raise questions or start discussions on what characterises science and scientists. Such questions or discussions could be:

Why are there only male scientists in the pictures? or *Do all scientists wear lab coats?* Many universities have portraits of researchers on their web pages (often including pictures); these could be used as a way to broaden the images of what characterises scientists.

When only 'facts' are described, NOS-related issues can still be discussed. In a book with facts about elephants, the teachers add important issues and messages by asking: *If we cannot hear the elephants speak, how can we know that they speak? Have we always known? Who has found out? What did people do to gain this knowledge? What equipment is needed to gain the knowledge? Are there also people who do research about elephants today?* The suggestions provided here have to be adapted to the age and experience of the children.

Finally, it is highlighted that the reflections presented are related to a project that we recently started in collaboration with a pre-school (children aged 1 to 6 years) where, together with a colleague, we are empirically investigating how reading books can be used to raise NOS learning situations. The idea of the project is for teachers to find ways to direct attention towards NOS issues during reading, in line with the suggestions made in this paper.

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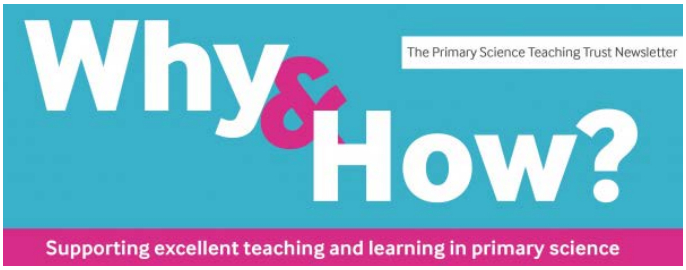

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Cutting-edge science research and its impact on primary school children's scientific inquiry

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● Tim G. Harrison ● Julia Nash ● Katherine Pemberton ● Paul Tyler ● Dudley E. Shallcross

Abstract
Cutting-edge science research can provide incredible stimulus to primary school children's emergent ideas in science. Devising science investigations that are allied to this cutting-edge science research helps to contextualise research. In this paper, we describe the methodology used to write articles for a primary school audience and some preliminary observations of class activities and responses.

Introduction

Teachers are encouraged to prepare children for careers they may undertake in the future that do not yet exist (e.g. Rocard *et al*, 2007). Creating resilient learners who are problem-solvers, able to gather and assess data, can work in teams and on their own, will facilitate just some of the traits that support children in any future career, whether or not it now exists (e.g. Archer *et al*, 2010). Providing a wide range of experiences, including outdoor learning, can also aid students in their advancement and preparation for the future.

It would be great to use current science research as exemplars and stimuli for teachers when doing science at primary school level. This would also help to prepare children for the future and enrich their science experience. But how can we achieve this? We could look at the news and follow up on relevant science articles, but this limits what we might look at. How can we obtain access to the science research in more detail if we need or want to? We could use the Internet or social media to track down articles, but where would we start? Would we be able to understand the science if we could, and how could we be sure that sources are reliable? Do we have the time or confidence to link this science to an investigation or discussion at a primary school level?

In an emerging project, PSTT (Primary Science Teaching Trust) Fellows (teachers who have won the UK Primary Science Teacher of the Year Award) (Shallcross *et al*, 2015) who have obtained a PhD in a science discipline and are now primary school teachers have been working with the PSTT CEO, who is a university-based scientist, to gather together recent research papers containing science, which can be used as exemplars in primary school science. In this article, we briefly look at some of these articles and discuss their impact on the emergent science understanding of children in the class. We define 'cutting-edge science research' here as research papers that have been published within the last two years in peer-reviewed journals.

Methodology

Access to current research is changing, as many journals are now open access, meaning that anyone can go to the journal website and read the papers. However, this is a time-consuming process and there is no guarantee that it will yield a paper that matches with the primary science curriculum in any country, let alone in the UK. Therefore, we have established a team of primary school teachers who have been research scientists and, working with them, PSTT is now building up a bank of research papers that have been summarised into an accessible article, together with ideas for investigations that can be carried out in the classroom and which support students in understanding the research paper. At present, these articles appear in the PSTT *Why and How* newsletter, but PSTT aims to publish an article on its website at least once every month from September 2019.

Exemplar articles

Greenland sharks (Shallcross, 2017)

In this paper, students are told how, in 2016, Professor Julius Nielsen (Nielsen *et al*, 2016) and colleagues published a paper in which they estimated that Greenland sharks could live for nearly 400 years. They worked out a way to use the length of the shark to estimate its age and the methodology is discussed in the accessible article (Shallcross, 2017). What was the impact on the children in covering this paper? In a Year 5 class (age 10), the children were told about the sharks and how the scientists worked out their age and were challenged to see whether they could construct a graph of age versus height from the members of the class. They were then asked if they could use a graph developed from the study to allow them to work out someone's age if they knew the person's height.

Figure 1 shows the graph that Class A in Year 5 constructed. Firstly, working in threes, the children measured each other's heights and checked their calculated age. Secondly, they added their data to a spreadsheet and plotted the graph. At this stage, some points looked very different from the rest. This was because, for one student, the height had been measured in inches not centimetres and, for another, the age of the child was 365 days too few. Once rectified, the graph was drawn and used to work out the age of other children and staff. The age estimates for children in other classes were reasonable, but the estimates for the teachers were flattering (i.e. all were too young). The children wondered about the intercept and what that meant? How could you be about 66 cm tall when you were born? The children researched the length of newborn babies and found out that this is on average about 50 cm. So, not unreasonable, but probably a bit large – maybe the children in this class were much taller than average? They considered whether they were longer than average as babies and why the adult's height was not a good predictor of their age. Again, this prompted some interesting discussions, where the children noted that people stop growing when they become adults, and some suggested that this is why we call people 'adults'. They then compared this finding with the Greenland shark, which continues to grow throughout its life. Numerous questions were posed and discussed by the children, such as why does the shark live for so long? Is there something special about the waters around Greenland? Do other sharks live that long? Other interesting discussions were prompted by the large number of researchers who contributed to the research and the fact that they were from many different countries. The children wondered why they were all needed and how they managed to work together.

Making drinking water from salty water using a molecular sieve (Shallcross, 2018a)

In 2017, Professor Rahul Nair and his team from Manchester University published a paper showing that it was possible to use graphene nanotubes

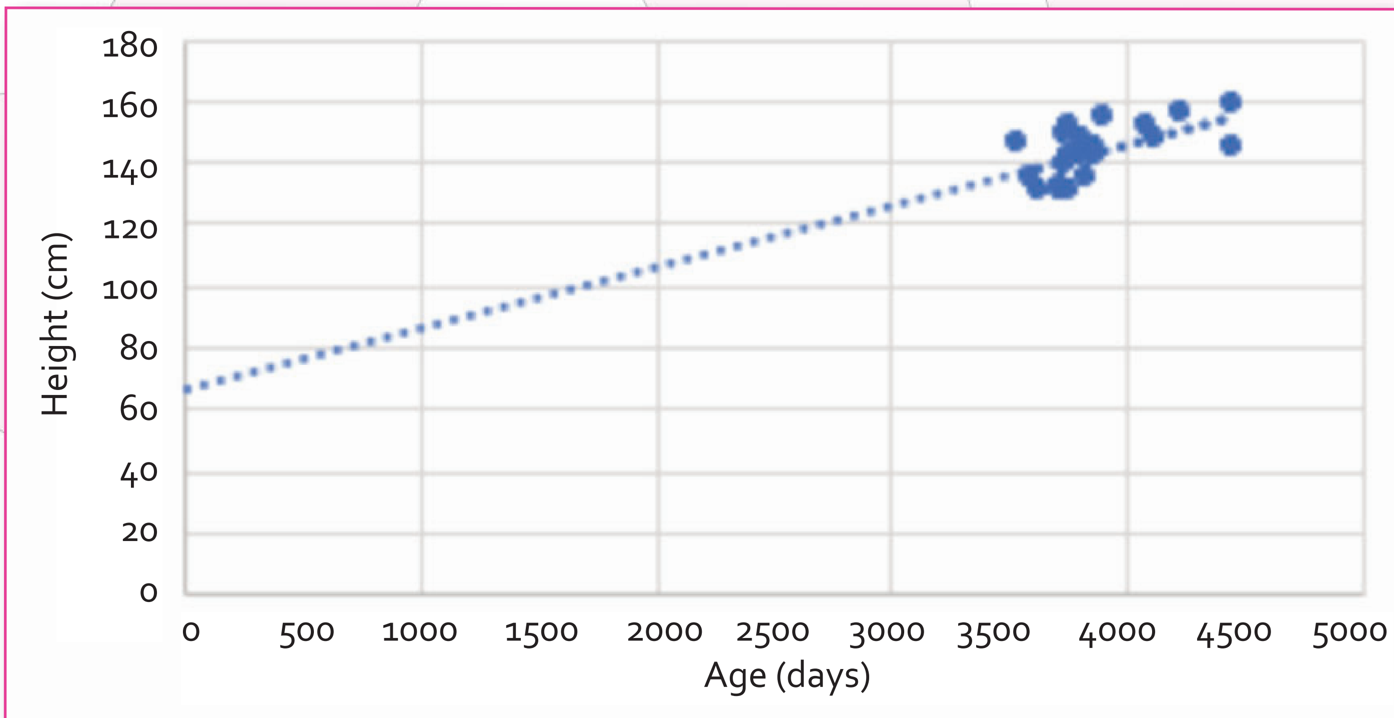

Figure 1: Plot of the relationship between age and height in Class A.

(see Shallcross, 2018a for an explanation) to separate salt from seawater. There is still a long way for the research to go to develop a commercial device that can be used by people, but the principle is exciting and, if it can work, it will make drinking water available to many people around the world.

This research was introduced to children in a Year 2 (age 7) class. They discussed what a sieve was and how it might be used to purify water. The children then got into teams and made their own sieves from a wide range of materials and used them to separate a wide range of mixtures. Figure 2 shows some examples of the sieves that the children in Year 2 devised.

The children had access to whatever they could find in the class to make their sieves. They found objects that were already sieve-like, they tested materials to see whether they could weave them into a sieve (as they had noted that fabric might make the best sieve: fabric has holes and is woven), they constructed tube-like sieves out of Lego and tested whether objects would pass cleanly through or get stuck. One child observed that, if a tube was 'wiggly', objects would be more likely to get stuck and therefore would make a better sieve. The children tried to make the holes as small as possible but still let water through. Once they had made their sieves, they tested them with dirty water.

As you might guess, some sieves worked better than others and more questions were then posed. The children carried out their own investigations and came up with a variety of conclusions. They linked these conclusions back to their initial predictions themselves, avidly trying to explain the science. The teacher had a 'wow' moment here, as this normally requires a teacher to explain to 6 and 7 year-olds what is happening.

Planetary hide and seek: is there a ninth planet in the Kuiper Belt? (Shallcross, 2018b)

The Kuiper Belt is a ring of rocks of varying sizes at the edge of our solar system, beyond the planet Neptune. Scientists have wondered whether there is a planet hiding in the Kuiper Belt – why do you think that it is hiding? The Kuiper Belt is a long way away and telescopes cannot see all the rocks in this zone. Professor Renu Malhotra and Kathryn Volk have studied the Kuiper Belt, using a telescope, and noticed that some objects seemed to be moving in

Figure 2: Children in Year 2 constructing different sieves.

a strange way. The best explanation they could provide for their movement would be that there is a large planet nearby that is tugging on them as they go past through the action of gravity. Through careful analysis, they estimated that a planet approximately the size of Mars may be present.

In a Year 2 class, the children were told about the research and challenged to come up with suggestions of how to detect the ninth planet (see Figure 3). They worked in groups of three and were given just 20 minutes to discuss, and create a presentation. The teacher remarked that this was one of the most exciting experiences in his/her teaching career. The wide variety of ideas presented showed incredible understanding of and insight into science among children in general, something that may not be revealed very easily. The children wanted to add four lenses to a telescope. A magnifying lens makes things bigger and so the more there are the more magnified the object would be. The children also said that they wanted to send the telescope on a satellite closer to the Kuiper Belt and look at it from different directions. They thought about getting rid of the asteroids in the belt but then decided there were far too many. They then used every bit of knowledge about space exploration, the planets and asked a lot of 'What if we did this?'-type questions.

This research was carried out by two female scientists and this prompted some positive discussions too. One girl said *'I know girls can be scientists but boys are still better at finding things out than girls'.* So, we still have work to do, even at this young age, to break down ingrained ideas.

Summary

In this preliminary study, we have shown how it is possible to use cutting-edge science research in a primary school setting. Early work suggests that these articles provide science experiences that have purpose and are memorable. The teachers and children enjoyed using them and they provided young children with a connection to science research that is taking place now. We are now producing a supporting teacher guide for each article. Teachers who have used these articles have stated that:

'I used the shark paper this morning and it was brilliant. Having read the articles, when they carried out their investigations, the children showed more commitment than I've seen in previous enquiries because they felt like they were carrying out "real" research. Additionally, pupils who did not normally join in science discussions ventured suggestions.'

'Showing the children a real article and talking about all the people that worked on the paper made science real to them.'

'Children remembered more about the science and there were more wow moments for me as a teacher than I have experienced before.'

For UK teachers, the new Ofsted framework encourages 'reading across the curriculum'; these papers fit in really well with that and were well received by the school's senior management.

We would welcome your comments on this paper and the science articles being produced. If you are a primary school teacher and use these articles, we would welcome feedback, and if you have subject

Figure 3: Year 2 children working out ways to detect the ninth planet and presenting their ideas to the class.

areas about which you would like to have a cutting-edge science research article, please e-mail PSTT at info@pstt.org.uk. We are currently writing the teacher guides to accompany these articles and feedback on these would be very welcome.

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why & how? PRIMARY SCIENCE TEACHING TRUST

Science Days leading to Science Weeks: Why have them?

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Abstract
Dedicated days to science, extending to week-long events (Science Weeks) can have myriad positive impacts on science teaching. A short review of the literature concerning days or longer time dedicated to science is provided, followed by some short case studies of work generated by primary school teachers. The aim of this article is to start to marry practice-based work in schools with the wider research base. Here, we look at the impact of Science Days/Weeks on: community links, whole school teaching, changing the attitudes towards science and the myriad experiences that science can afford.

Introduction

In the second of this new style of paper for *JES*, we are seeking to take teachers' experiences in school, through case studies, action research etc. and set them in the context of the wider research literature. There is no attempt to make the teachers' contributions definitive (i.e. these are teachers' reflections), but instead we link themes that emerge from their experiences with known research in the field. In this article, we will focus on the use of dedicated Science Days/Weeks. In the UK there is a national Science Week (https://www.britishscienceweek.org/) in March each year, which is a focal point for science activities. However, in primary schools it can be difficult to bring in science-based organisations and people in that particular week, as there are so many groups wanting to have a visit. Other activities on a regional and national basis exist, such as the Great Science Share (https://www.greatscienceshare.org/), which is a day of science in June each year. However, these activities can be run at any time of the year to suit the school and there are many benefits to running a Science Day/Week at a primary school, including:

- A day through to a week dedicated to science raises its profile in the school and the community, and can connect the school with its neighbourhood and further afield (e.g. Dillon *et al*, 2005);
- Depending on the type of dedicated science time, a dedicated science experience may bring local and national experts from different areas of science, engineering and medicine into the school to share their experiences and expertise (e.g. Stem Ambassadors in the UK: https://www.stem.org.uk/stem-ambassadors). These experts may be parents or other relatives of schoolchildren and might increase investment in the school or represent local or national organisations that may become long-term supporters of the school (e.g. Harrison *et al*, 2009);
- If there is a show-and-tell evening or event, this can bring in members of the family (e.g. fathers) who may not often come into the school (e.g. Watts, 2001);
- Teachers have an opportunity to work together on projects and planning in science and, in many cases, activities can cut across year groups;
- Science Days/Weeks can promote and share best practice in teaching across the school, not only in science;
- Local themes and focal points can be used, as well as national and international events. It has been noted that primary school children show knowledge and skills that are not always displayed in a classroom, when they have the opportunity to work as they do out of school and on topics of interest to them (e.g. Masingila *et al*, 2011; Morgan *et al*, 2017);
- Children can be encouraged to share their cultural variations around a science theme (e.g. Grimshaw *et al*, 2019); and

- These dedicated times engage boys and girls and, as we shall see (Thompson, 2014), are particularly good for children from minority groups. If there is no formal assessment, these times can allow children and teachers to engage, explore and learn in different ways.

Case studies

In this section, Fellows of the PSTT College (Shallcross *et al*, 2015) reflect on their experiences of dedicated Science Days/Weeks.

Case Study 1: Evolution of an annual Science Day

It is important to note that a Science Week is not the necessary first objective: establishing a Science Day may be a sensible starting point. A Fellow reflects on being a newly appointed Science Subject Leader:

In my first year, I wanted to engage the staff in practical science. I emptied the resources cupboard, planned activities for all year groups, enlisted the Year 6 (age 11) pupils to run stalls and timetabled each class with their teachers to have time in the hall to discover and explore what was available to use for practical science. I split the day into two parts suitable for each key stage, so the teachers were in no doubt as to what they could use for future planning in their own classrooms. This worked well, as teachers were unaware of the resources and their capacity to be used for practical science.

The following year, I moved the experience on further by swapping classes with the Year 6 teacher, one afternoon a week for 4 weeks after SATs, to allow the Year 6 pupils to plan their own stalls. We began the day with an assembly, inviting Governors and parents to come along and get involved, and this was planned and led by the Year 6 pupils. Once again, pupils visited the stalls as a class and experienced age-appropriate activities. This increased the confidence of the Year 6 pupils in their ability to plan and execute practical investigations.

The next year, we used the same format as the previous one, but this time we started with the theme of 'Water' to give the Year 6 pupils a greater challenge and encourage them not to replicate previous activities. Practical Action resources helped the pupils to plan their assembly, setting the scene for the importance of water across the world (see https://practicalaction.org/schools/search/Water/tags:ks1,ks2). This approach to developing a Science Day gradually over time with established staff in a relatively small school worked well. The Day became embedded in the school calendar and each year staff became more and more involved, until the whole day was given over to science and each class produced displays related to the theme chosen by the Year 6 pupils for that particular year. We have run the day at the end of the spring term instead of during the UK National Science Week in March, so that we could utilise the outdoors (e.g. Grimshaw *et al*, 2019).

Case Study 2: Ethnicising Science Weeks

Organising a Science Week with a different theme each year is always a challenge. It must tick many boxes, such as not being too onerous for an overworked staff, and be engaging for our pupils, and so on. For our school, where most children have an Asian heritage background with varying degrees of spoken and written English, finding a topic that would encourage parents and carers to come into school and take an active role in the science curriculum was a challenge.

After a science lesson one day, I was commending one child who had been particularly on task and was able to help his/her group reach an understanding about the scientific concepts involved. When I told the child that s/he was definitely a scientist of the future, s/he said, *'Muslim people don't do science'.* Eager to disprove this, I set about looking on the Internet for examples of Muslim scientists. The 1001 Inventions organisation is an international science and cultural heritage organisation, which raises awareness of the creative golden age of Muslim civilisation that stretched from Spain to China (http://www.1001inventions.com/). There had been an exhibition in London at the Science Museum in 2010 and this has since toured the world.

The following areas formed the basis of the exhibits and interactive experiments (see Figure 1):

Home: The thousand year-old inventions that still shape everyday life;
Market: How influential ideas spread through travel and trade;

School: Learning, libraries and their links with the past;
Hospital: How ancient approaches to health have influenced today's medicine;
Town: Why East and West share so much architectural heritage;
World: The explorers of a thousand years ago; and Universe: How ancient astronomers expanded our view of the universe.

The 1001 Inventions website provides a wealth of downloadable resources and information about different scientists. Each class had a practical task to complete and had to make an information board about the product and the scientist who had influenced its development.

One of the main features of the 1001 Exhibition was a giant model of the clock built by the engineer Al-Jazari over 800 years ago. This automatic Elephant clock used water technology – a great example of the Muslim origins of modern automation and robotics. It also celebrated the diversity of contributions to scientific discovery by having, as part of its design, the use of Greek scientific principles, an Indian timekeeping device, an Indian elephant, an Egyptian phoenix, Arab mechanical 'men', a Persian carpet and Chinese dragons.

The whole school was set the task of making a model of the clock as a competition to be completed at home. The week started off with a whole school assembly showing the film that accompanied the exhibition, *The Library of Secrets.* This made a big impact on the pupils and created a sense of excitement about the week ahead. We also set a quiz based on the scientists upon whom we were focusing to send home for families to research together.

At the end of the week, we had a family celebration day (see Figure 2), where each class showcased their activity and their display board to explain their task. There were mehndi and calligraphy workshops, with contributions from a local cosmetics company who came and made bath bombs with the parents and children. The local college also sent some of their health and beauty students to give manicures. The event finished with a celebratory meal cooked by some of the parents.

Figure 1: A Science Week based on the 1001 Inventions project, highlighting Muslim contributions to science.

The impact on pupils and parents was quite extraordinary. Pupils spoke with pride about the discoveries of the scientists they had researched and science as a career seemed to be more of an option. Parental feedback was so positive, breaking down barriers for some parents who hadn't really engaged with school events before. We also had a high percentage of female relatives attending. Recognising the impact of Muslim culture on science is something that has been lost in translation over the years. The 1001 Inventions resources allow these discoveries to be celebrated and given the recognition they deserve. Therefore, it is possible to run ethnicised Science Weeks (Days), and the impact on the whole school and local stakeholders is marked.

Figure 2: An exhibit from the celebration evening from the Science Week based on the 1001 Inventions project.

Case study 3: Tapping into the science within a school community

Like many schools, our Science Weeks are valued as an integral part of the school's calendar and we have been running them for many years. Why do we continue to do so when the curriculum is so full, and time is of a premium? How does this one week become more than just one week only, and not be viewed as a box-ticking exercise but, instead, as a key event that has lasting impact?

Put simply, Science Weeks are enormously engaging, raise the profile of the subject well beyond their duration and can affect more than the immediate school environment. One approach that illustrates these benefits is best termed 'Tapping into the science within the school community'. We often, quite rightly, identify the need to enrich children's experience and knowledge of science; the term 'science capital' (e.g. Archer *et al*, 2015) has become a key development focus in schools. Science Weeks offer a superb collaborative opportunity to find and celebrate the science that one's school community has to offer – a 'Whole School Science Capital' resource. Writing and talking to parents and the school community well in advance, and asking them to be part of Science Week, has led to some amazing contributions. Over the years our school community has provided our children with:

- A tank/artillery gun, complete with 20' barrel and caterpillar tracks;
- A scale model steam train, the track extending around the playground;
- Large scale ropes and pulleys used by small groups of children to pull a 4x4 vehicle;
- Local farmers providing livestock, including hens' eggs and chicks, sheep and horses;
- A helicopter landing on the school playing field (one very cold winter day, one very cold Ofsted Inspector);
- Local hospital surgical teams enhancing hygiene and prevention of infections;
- Sharing a parent's Art skills by linking between Art and science through exploring light and shadow;
- Revealing the strength of paper in a workshop on engineering by bringing in a section of a Chinook's rotor blade (inside, they are made of paper);
- A genuine Enigma machine, upon which we were all allowed to make our own coded messages; and
- The landing of a group of parachutists on the field.

Some of the most rewarding outcomes have been hearing comments such as *'Wow, is that your dad?'* and *'I didn't know your mum did that!'* as well as new volunteers, seeing the variety and encouraged by the excitement, emerging to offer input into the curriculum at other stages of the year.

Although we may be very fortunate, we recognise that each school's context is different. However, by asking your school and wider community and giving those in it encouragement and offering support, you can tap into the science on your doorstep, with some outstanding results.

Summary

Peterson and Treagust (1998) and other researchers have noted the value of problem-based learning approaches to science teaching at primary school in general. Themes and challenges (as noted previously) are a great way to scaffold a Science Day through to a Science Week. There are myriad potential themes and challenges that can be used. In addition, such days and weeks:

- Raise awareness of science within the school community and value children's backgrounds and connections;
- Recognise and encourage parental and community involvement, which can be extended or built upon; and
- Reinforce that science is everywhere, and the variety of societal links, both explicit and implicit.

In this paper, we have highlighted some of the benefits of dedicated Science Days through to Science Weeks. We would welcome your comments on this article. If you are a primary school teacher and have Science Day/Week experiences that you would like to share, we plan to write a follow-up paper in a future edition, which collates these reflections and comments. If you want to run a Day or Week, or if you disagree with elements of the article, we would like to hear from you too. Please e-mail PSTT at info@pstt.org.uk

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Resource Review

Mastering Primary Science
By: Amanda McCrory and Kenna Worthington
Published in 2018 by Bloomsbury Publishing
Price: £17.99 Pb
ISBN: 978 1 474277 43 3

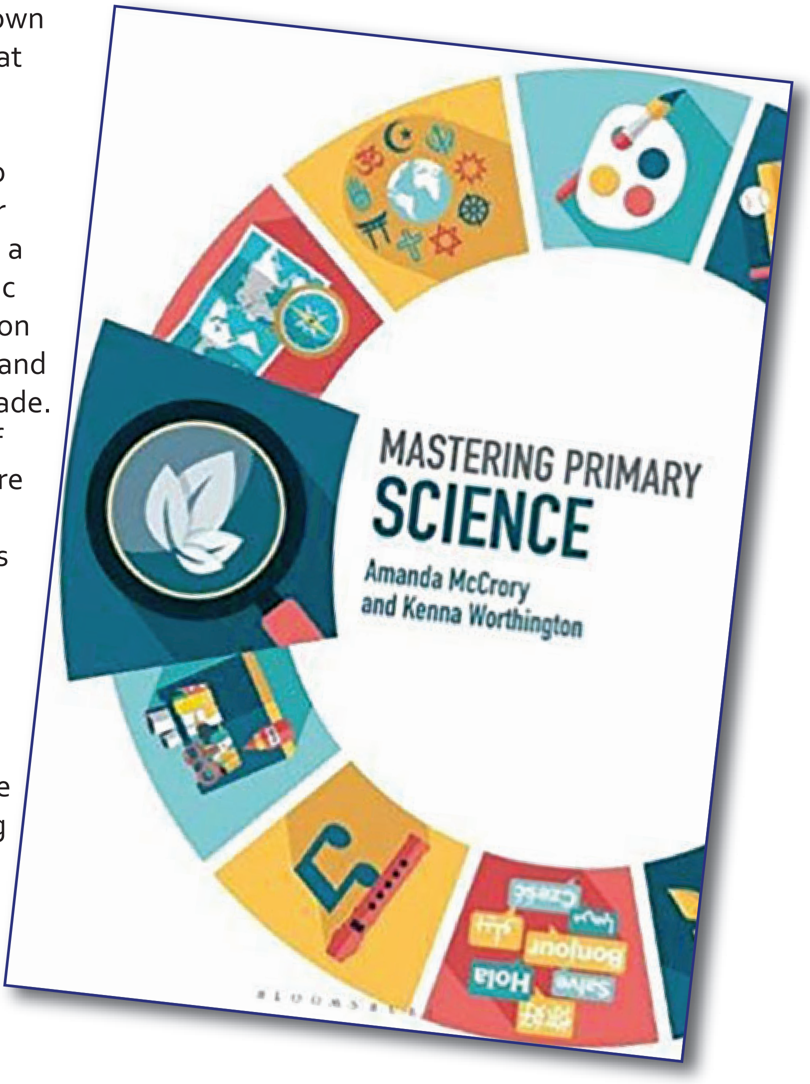
This book forms part of the *Mastering Primary Teaching* series, which tackles different curriculum areas in the primary curriculum. This book focuses on primary science and considers various issues related to the teaching of science to young children.

It starts with asking readers to reflect on their own personal views of the nature of science and what they believe is involved in doing science with primary children. It puts forward arguments on how science promotes children's enthusiasm to investigate the world around them, follow their curiosity, and be more creative as they develop a knowledge and understanding of basic scientific concepts and inquiry skills. A strong argument on the contribution that science makes to society and how scientists work creatively to innovate is made. In addition, the book also provides examples of children's work to illustrate how issues raised are reflected in practice. Other important aspects related to classroom practice, such as children's ideas, and assessment, are also considered.

The book is written in a fresh and easygoing style, which encourages one to read on. The flowing text also promotes a positive view of primary science and encourages readers to take on the challenge of planning and implementing engaging science activities. The practical examples and the direct references to the curriculum make science accessible to all teachers, even those who do not feel so confident in science.

This book is thus appropriate and recommended for student teachers as well as those teachers who wish to improve their practice and get children more engaged in learning science effectively.

Suzanne Gatt



Contributing to JES

About the journal

The *Journal of Emergent Science (JES)* was launched in early 2011 as a biannual e-journal, a joint venture between ASE and the Emergent Science Network and hosted on the ASE website. The first nine editions were co-ordinated by the founding editors, Jane Johnston and Sue Dale Tunnicliffe, and were the copyright of the Emergent Science Network. The journal filled an existing gap in the national and international market and complemented the ASE journal, *Primary Science*, in that it focused on research and the implications of research on practice and provision, reported on current research and provided reviews of research. From Edition 9 in 2015, *JES* became an 'open-access' e-journal and a new and stronger Editorial Board was established. From Edition 10, the copyright of *JES* has been transferred to ASE and the journal is now supported by the Primary Science Teaching Trust (PSTT).

Throughout the changes to *JES*, the focus and remit remain the same. *JES* focuses on science (including health, technology and engineering) for young children from birth to 11 years of age. The key features of the journal are that it:

- is child-centred;
- focuses on scientific development of children from birth to 11 years of age, considering the transitions from one stage to the next;
- contains easily accessible yet rigorous support for the development of professional skills;
- focuses on effective early years science practice and leadership;
- considers the implications of research into emergent science practice and provision;
- contains exemplars of good learning and development firmly based in good practice;
- supports analysis and evaluation of professional practice.

The Editorial Board

The Editorial Board of the journal is composed of ASE members and PSTT Fellows, including teachers and academics with national and international experience. Contributors should bear in mind that the readership is both national UK and international and also that they should consider the implications of their research on practice and provision in the early years.

Contributing to the journal

Please send all submissions to: janehanrott@ase.org.uk in electronic form.

Articles submitted to *JES* should not be under consideration by any other journal, or have been published elsewhere, although previously published research may be submitted having been rewritten to facilitate access by professionals in the early years and with clear implications of the research on policy, practice and provision.

Contributions can be of two main types; full length papers of up to 5,000 words in length and shorter reports of work in progress or completed research of up to 2,500 words. In addition, the journal will review book and resources on early years science.

Guidelines on written style

Contributions should be written in a clear, straightforward style, accessible to professionals and avoiding acronyms and technical jargon wherever possible and with no footnotes. The contributions should be presented as a word document (not a pdf) with double spacing and with 2cm margins.

- The first page should include the name(s) of author(s), postal and e-mail address(s) for contact.

- Page 2 should comprise of a 150-word abstract and up to five keywords.
- Names and affiliations should not be included on any page other than page 1 to facilitate anonymous refereeing.
- Tables, figures and artwork should be included in the text but should be clearly captioned/ labelled/ numbered.
- Illustrations should be clear, high definition jpeg in format.
- UK and not USA spelling is used i.e. colour not color; behaviour not behavior; programme not program; centre not center; analyse not analyze, etc.
- Single 'quotes' are used for quotations.
- Abbreviations and acronyms should be avoided. Where acronyms are used they should be spelled out the first time they are introduced in text or references. Thereafter the acronym can be used if appropriate.
- Children's ages should be used and not only grades or years of schooling to promote international understanding.
- References should be cited in the text first alphabetically, then by date, thus: (Vygotsky, 1962) and listed in alphabetical order in the reference section at the end of the paper. Authors should follow APA style (Author-date). If there are three, four or five authors, the first name and *et al* can be used. In the reference list all references should be set out in alphabetical order

Guidance on referencing

Book

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Manuscripts are sent for blind peer-review to two members of the Editorial Board and/or guest reviewers. The review process generally requires three months. The receipt of submitted manuscripts will be acknowledged. Papers will then be passed onto one of the Editors, from whom a decision and reviewers' comments will be received when the peer-review has been completed.

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These should be addressed and sent to Jane Hanrott (JES), ASE, College Lane, Hatfield, Herts., AL10 9AA.

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